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NAME OF AUTHOR/*NOM DE L'AUTEUR* Michael Scot McClure

TITLE OF THESIS/*TITRE DE LA THÈSE* Aspects of Urban Runoff from the Edmonton Area and its Effects on the North Saskatchewan River

UNIVERSITY/*UNIVERSITÉ* Alberta

DEGREE FOR WHICH THESIS WAS PRESENTED/*GRADE POUR LEQUEL CETTE THÈSE FUT PRÉSENTÉE* M.Sc.

YEAR THIS DEGREE CONFERRED/*ANNÉE D'OBTENTION DE CE DEGRÉ* 1974

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THE UNIVERSITY OF ALBERTA

ASPECTS OF URBAN RUNOFF FROM THE EDMONTON AREA AND ITS EFFECTS ON THE NORTH SASKATCHEWAN RIVER

by

MICHAEL SCOT McCLURE

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

OF

MASTER OF SCIENCE

DEPARTMENT OF CIVIL ENGINEERING

EDMONTON, ALBERTA

FALL, 1974

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled ASPECTS OF URBAN RUNOFF FROM THE EDMONTON AREA AND ITS EFFECTS ON THE NORTH SASKATCHEWAN RIVER submitted by MICHAEL SCOT McCLURE in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE.

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ABSTRACT

ASPECTS OF URBAN RUNOFF FROM THE EDMONTON AREA
AND ITS EFFECTS ON THE NORTH SASKATCHEWAN RIVER

The object of this study was to determine the quality or runoff as the result of snowmelt, storm runoff and combined sewer overflow and to evaluate the effect of these waters on the North Saskatchewan River.

All samples were taken manually. The quantity of flow was obtained for the storm runoff but not for snowmelt or combined sewer overflows.

The runoff from snowmelt had little impact on the North Saskatchewan River, however, sufficiently high concentrations of lead, zinc, copper, ammonia and oils and greases were found that toxic effects might occur in some species of fish if the runoff were discharged into a receiving stream which could not provide adequate dilution.

The solids concentration in storm runoff was extremely high. The BOD-5-20 concentration was as high as 108 mg/l and averaged 51 mg/l. A relationship between total flow and total BOD-5-20 loading was formulated to be:

$$L = a \log Q_t + b$$

in which L is the loading, Q_t is the total flow and a and b are constants related to the drainage basin characteristics.

Combined sewer overflow had an average BOD-5-20 strength of 258 mg/l the highest being 407 mg/l.

The runoff from the City of Edmonton had a noticeable effect on the North Saskatchewan River. The solids and BOD-5-20 concentration increased considerably while the dissolved oxygen dropped. Dissolved oxygen sags of 1.2 and 0.4 mg/l below ambient conditions were recorded. It was estimated that the deoxygenation rate coefficients required to produce these sags would be 0.88 and 0.66 per day respectively.

ACKNOWLEDGEMENTS

This investigation was guided by Mr. P. H. Bouthillier, Professor of Sanitary Engineering, Department of Civil Engineering, University of Alberta. His assistance and comments provided throughout the investigation are greatly acknowledged.

I also wish to express my sincerest appreciation to:

The staff of the Edmonton Main Sewage Treatment Plant for collecting samples;

Mr. W. Korsch and the staff of the Environmental Health Laboratory for the use of their equipment and assistance in performing analyses;

My parents for their support and encouragement during my education;

My wife and family.

The financial assistance received from the Alberta Department of Public Health for this investigation is gratefully acknowledged.

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CHAPTER I

INTRODUCTION

I-1 General

The concentration of large populations into urban areas has produced many problems with the surrounding environment. The volume of wastes produced by these areas is often too large to be readily assimilated by natural processes. Until the present century little effort had been made to compromise with the environment; however, with increasing pollution of both air and water, an awareness has developed that the supply of these vital elements may become too contaminated to use. Many agencies are seriously trying to reduce pollution, yet often the nature, source and the solution for the problems caused by many pollutants is unknown or questionable.

A source of pollution which is generally ignored is surface runoff from urban areas. Although recognized as a possible pollution source in the late nineteenth century, most authors since then have thought of it as being relatively harmless. Studies since 1950 (some of which are presented in Chapter II) have indicated that street runoff can be a major pollution source and merits more study.

The objective of this project is to assess the pollution potential of street runoff from rainfall and to compare the effects of runoff from separate systems as against combined sewer overflow. A brief study was also conducted on the pollutional effects of street runoff from snowmelt.

I-2 Development of Sewer Systems

Most of the large cities started to develop sewer systems before 1900. Early household wastes were discharged to priveys, cess-pools or vaults; the drainage systems being used for storm runoff only. With the installation of the first pulic water supplies about 1800 and with the development of the water closet (patent in the United States in 1833), loads became too heavy for the household systems in built-up areas. From necessity it became permissable and then mandatory to discharge household wastes into the street drainage system - thus the development of the combined sewer.

In the early systems the main sewers were often natural water courses which had been channelled or enclosed and these followed a direct route to the receiving water. If the receiving water supplied sufficient dilution, the system was complete and no further development was necessary. If, however, the sewage caused a pollution problem it would be transported to a site downstream or to an area where more dilution was

available. This is done via trunk sewers with capacities for peak wet weather flows or by intercepter sewers with capacities for dry weather flows and allowance for by-passing wet weather flows. The latter sometimes developed from trunk sewers when the peak wet weather flows exceeded the capacity due to increased drainage area. Sewage treatment plants developed in the late nineteenth century in areas where it was uneconomical to transport the sewage to a site that would supply suitable dilution or because the contamination produced problems downstream. Where sewage treatment plants are served by combined sewers the capacity is usually only sufficient to handle the dry weather flow. Wet weather flows are by-passed either at or before the treatment plant.

Separate sewer systems with separate conduits for storm runoff and for sewage were advocated as early as 1842. In this system the storm water is discharged into the nearest water course while the sanitary sewage is transported to treatment plants before disposal. The practicalness of these systems was questioned by Dr. Hering, (2) who noted in 1881 that: "The principal of separation, although often ostensibly preferred on sanitary grounds, does not necessarily give the system any decided advantage over combined, except under certain definite conditions. On all others preference will depend on the cost of both construction and maintenance which only a

careful estimate, based on local requirements, can determine". Later in 1930 Metcalf and Eddy (2) stated: "It may be undesirable to allow storm water from urban districts to contaminate neighboring bodies of water, not only because of sanitary objections but because of the disagreeable appearance of accummulation of refuse or deposits of sediments forming on the bottom of these water courses, floating matter and slick. Such conditions in many cases make necessary an extensive drainage system which might as well be used to remove sewage, thus avoiding the additional expense of a dual system". Between 1930 and 1950 the consensus changed as expressed by Phelps:(1) "The ideal plan, from the standpoint of the entire water contact cycle, is the use of two completely independent systems...; for sanitary sewage must be treated while storm water need not be".

I-3 Combined Sewers in Canada

During 1968 Dr. D.H. Waller (2) of the Nova Scotia Institute of Technology conducted a mail survey of combined sewers in Canada. He sent a four page questionnaire to 86 communities thought to represent most of Canada's combined sewer population. The questions were designed to ascertain the extent and distribution of combined sewer systems; the attitudes and policies regarding combined sewers, factors affecting present attitudes and policies, and information on methods to reduce the volume or frequency of overflows.

From his survey Waller concluded that 37% of Canada's population, or 53% of the sewered population, is served by combined sewers. He found that 14% of the combined sewers were placed before 1900, 34% between 1900 and 1920, 11% between 1920 and 1940 and 41% since 1940.

In response to the question "Are combined sewer overflows considered to cause problems?" twenty communities with populations between 19,000 and 1.6 million and three metropolitan authorities answered "Yes". The reasons given were (some listed more than one reason):

Floating debris objectionable	8
Offensive to users of abutting property	8
Property damage	2
Pollution of recreational areas	17
Land rendered unusable	0
Other reasons	3

Other reasons were: pollution 3, health 1, potable water supply 1, "government" 1.

In response to other questions Dr. Waller found that 25 of 38 responding communities extended combined sewers with separate sewers and 17 of 21 communities responding installed sanitary sewers "in most cases" or "where possible" when combined sewers are replaced. Eleven cities with populations between 22,000 and 700,000 serving 1.6 million people by combined sewers have or are planning separation programs. Three

other communities are considering separation. In addition to these separation programs an estimated 11% of Canada's combined sewers will be replaced by separate systems within the next 10 years because of poor conditions, urban renewal of inadequate capacity (primary reason).

I-4 General Attitude

In North America the question of whether to use combined sewers or separating sewers appears to be settled, with separate sewers being the accepted practice. This conclusion appears to be based on assumptions similar to Phelps' statement with little work being done to justify it on a cost benefit basis using separate systems versus properly designed combined systems. Cyril Gomella in his discussion of reference (11) said: "On the other hand, it is said that in the United States, 80 percent of the communities" (smaller communities) "have sewage networks with separate systems. The decision thus taken for this type of sanitation must be noted because, in other regions, the dispute (merely technical) between the advantages of a combined network and a separate network is not resolved."

CHAPTER II

SUMMARY OF PREVIOUS RESEARCH REPORTS

II-1 General

This chapter will outline some of the reported studies which are pertinent to this study. It is not intended to be a complete summary but is intended to supply background information.

II-2 Investigation of Urban Runoff and Combined Sewer Overflow

Detroit - Palmer (6)(10)

C. Palmer in 1949 studies low intensity storms in assessing combined sewer overflows in Detroit. It was found that 90 percent of the total rainfall was contributed by storms of 0.5 inches or less. The average volume of sanitary flow was equivalent to a runoff of 0.01 inches per hour. Runoff did not occur unless the rate of rainfall exceeded 0.03 inches per hour.

During his study Palmer found that Detroit's combined sewer overflows had a mean coliform counts of 4,300,000 MPN/100 ml, a mean five day BOD of 50 mg/l, and mean suspended solids of 250 mg/l of which 100 mg/l were volatile. Individual values varied plus 100 percent to minus 50 percent of the mean.

Palmer sampled street runoff before it entered the catch basin in 1949 and again in 1960. In 1949 he took a series of samples at one site, while in 1960 he took samples at various locations and times during the progress of the storm. The results of his 1960 sampling program is presented in TABLE A-1.

Palmer concluded that the cost of separating the Detroit system would be prohibitive and not justified from results which could possibly be obtained. He also stated: "The quality of storm water from a separate storm sewer serving an area such as Detroit would be very unsatisfactory and highly polluted".

Cincinnati - Weibel et al (4)(5)(11)

Between 1962 and 1964 the Rober A. Taft Sanitary Engineering Centre collected samples of stormwater runoff from a 27 acre, residential and light commercial section of Cincinnati, Ohio. This area was served entirely by a separate sewer system. It had a population density of 9 persons per acre and 37 percent of the surface was impermeable. Samples were collected by means of an automatic sampler. The results are shown in TABLE A-2.

In conjunction with this study, samples of rain water were taken to determine the degree of contamination before the rain reached the ground. A summation of the results is shown

in TABLE A-3.

To aid in determining the relevance of pollution from urban areas Weibel conducted a study on the pollution effects of rural runoff. Several small drainage areas were selected in Coshocton County, Ohio. The runoff from these areas was gauged and sampled. TABLE A-4 is a summary of the runoff constituents from drainage areas cultivated under prevailing practices in Ohio.

Weibel's reports concluded that rainfall and stormwater runoff from urban areas cannot be ignored in water pollution control problems. Although rainfall and stormwater runoff is intermittent, the constituents of runoff, when considering volume, can be many times that of raw sewage for the period of runoff.

Detroit and Ann Arbor - Burm and Vaughan (7)

For this study the two cities, Detroit (population of 1,670,000 served entirely by combined sewers) and Ann Arbor (population 67,300 served by separated systems) were chosen for comparison of the bacteriological quality of sewer discharge. In Detroit, a sewer system which served 25 percent of the city's population and approximately 22,000 acres was studied; in Ann Arbor a drainage area of 3,800 acres was chosen. Although most of the Ann Arbor drainage area was within the City, there was a significant amount of rural

drainage entering the system.

Samples were taken by automatic sampling devices with variable time cycles. Samples of combined sewer overflow in Detroit were taken at 15 minute intervals for the first month, after which the cycle was gradually extended to one hour. The interval between samples of storm drainage taken in Ann Arbor never exceeded five minutes. The samplers would start automatically when the discharge reached a certain stage. The samples were incubated within 24 hours and analyzed for total coliforms, fecal coliforms, and fecal streptococci. A comparison of the results is shown in TABLE A-5.

Several of the conclusions drawn from this study were:

1. Total coliform densities in combined sewer overflows often approached densities found in sewage.
2. Total coliform densities in storm drain discharges were judged to be approximately one tenth of those of combined sewers.
3. Fecal coliform densities were approximately 20 percent of the total coliforms in combined sewer overflow. There was approximately 40 times more fecal coliforms in combined sewer discharge as in separate storm sewer discharge.
4. Fecal streptococcus densities were remarkably equal in both systems, with discharges from combined

sewers having only twice the density as that of separate sewer discharge.

5. Initial counts from both combined and separate storm sewer discharges indicated that the effect of "first flushing" was minimal.
6. Total coliform and fecal coliform densities showed significant increases during the warmer summer months.

Detroit and Ann Arbor - Brum, Krawczyk and Harlow (8)

This study followed Burm's and Vaughan's 1963-64 bacteriological study and attempted to compare the physical and chemical properties of combined sewer overflows and separate sewer discharges. The same sites and equipment were used (equipment modified slightly to obtain larger samples) as in the previous study. Sampling intervals were again less than five minutes in Ann Arbor; however, in Detroit they varied from one to five hours. A summary of the results of this study are shown in TABLE A-6.

A few of the important findings of this study were:

1. The BOD in separate storm sewer discharges was about one-fifth of that observed in combined sewer overflows. Values of BOD showed little seasonal variation in separated storm drains; combined sewers however, had high values during the spring. In both bases concentrations of BOD lessened as

discharge progressed, indicating a flushing action.

2. Absolute values for all solids parameters were higher for separate sewer discharges in Ann Arbor, however, the hilly terrain of this city was more subject to erosion and scouring. The comparison of these parameters for the two cities was difficult.
3. Higher concentrations were observed in the combined sewer systems for phenols, BOD, ammonia nitrogen, organic nitrogen, soluble phosphates and total phosphates, while concentrations of suspended solids, volatile suspended solids, settleable solids, volatile settleable solids, and nitrates were higher in the separate sewer system.

Cleveland - Simpson and Curtis (14)

The object of this study was to determine the feasibility of a large stabilization-retention basin in the offshore waters of Lake Erie as a method of treating combined sewer overflows, polluted surface water and wastewater treatment plant effluent prior to discharge into Lake Erie. Data was collected during 1967 to determine the nature of these waters. Some of this information is presented in TABLE A-7. Combined sewer overflows were collected at several locations and varied greatly in quality.

TABLES A-8 to A-15 are summaries of studies into the composition of urban runoff and combined sewer overflow. The data presented was obtained from the previously mentioned studies and from reference (1).

II-3 Investigations into Source of Pollution in Urban Runoff

Chicago - American Public Works Association (13)

The American Public Works Association in a 1968 study in Chicago found that the average accumulation of street litter was between 0.5 and 8.0 lb/day/100 ft of curb, of this 0.4 to 5.2 lb/day/100 ft of curb was in the form of dust or dirt (material passing a 1/8 inch hardware screen and thought to be the component of street litter which readily causes chemical and bacteriological pollution. The weighted average of dust and dirt by land use was 1.5 lbs/day/100 ft of curb and the average weighted values for common pollutants were: "per gram of dry material, BOD-5,000 mg/l; COD-40,000 mg/l; nitrogen forms as N-400 mg/l; phosphates as PO_4-less than 50 mg/l; total bacteria counts greater than 10 million; coliforms MPN-more than 1 million; and fecial enterococci-5,400".

Using this data, and assuming a 14 day accumulation of litter and that all the chemical and bacteriolocial pollution will enter solution within two hours from the start of a storm, the relative BOD would be equal to 160 percent of the sanitary flow for the same period.

An evaluation of the street cleaning equipment indicated that it was ineffective in removing dust and dirt.

A study was also conducted on the salt content of runoff from snow melt. The average concentration in the runoff from Chicago's expressway was 14,000 mg/1 and there appeared to be almost complete recovery (all salt applied was accounted for in the runoff). Hexavalent chromium, a chemical rust preventative added to the salt, appeared in amounts as high as 116 mg/1.

Cincinnati - Geldreich et al (17)

This study attempted to determine the source, survival and health hazard of organisms in stormwater. Samples of runoff were taken from suburban street gutters, a wooded area bordering a city park, a suburban business district and agricultural land.

The study concluded that the runoff from all urban areas had bacteriological composition similar to runoff from cultivated land. Fecal coliform averaged 8.6 percent of the total coliforms (7.6 percent for Weibel). The fecal coliforms in stormwater in urban areas was attributed to cats, dogs and rodents.

Studies of bacterial survival in stormwater indicated organisms persisted at higher levels for winter studies (10°C) than they did for summer studies (20°C).

CHAPTER III

SAMPLING AND TESTING

III-1 General

For this study a series of samples of urban runoff and combined sewer overflow were obtained during periods of runoff or overflow. The samples were analyzed in the University's Sanitary Engineering Laboratory and the Alberta Department of Health's Environmental Health Services Laboratory (now the Department of the Environment). Samples of runoff from snow melt were taken during March. Samples of urban runoff, combined sewer overflow and river water were taken during May, June and the first half of July.

The storms during the Spring and Summer were mostly classified as "thunderstorms" or"thundershowers". These are difficult to forecast since they can develop and disperse in small areas and travel in a narrow band. Since all sampling was manual it was difficult to ensure that the author was near the sampling site when it rained. However, the samples collected are felt to be representative of the storm runoff and combined sewer overflow for the storms studied.

It originally had been intended to sample the stormwater manually at an outfall and the combined sewer overflow

by an automatic sampler at one of the City's sewage treatment plants. An automatic sampler was obtained from the Alberta Department of Health. Unfortunately the sampler sampled at two hour intervals whereas 10 to 15 minute intervals were desired. Attempts were made to alter the sampler but with only moderate success. This plus the fact that the automatic depth measuring gauge (that was to be used to gauge discharge), did not arrive until late June, resulted in the abandoning of the intended automatic sampling station. Sampling was therefore carried out manually.

III-2 Combined Sewer Overflow

The Edmonton Number Three Sewage Treatment plant by-pass was initially chosen for sampling of overflows since 45 percent of the area it services has combined sewers (see FIGURE F-3). The main disadvantage of this site was that the amount of by-pass was not measured as part of the plant's operation and there was no suitable site for measuring it manually. Samples were taken at this plant on May 13 and May 27, 1969.

After May 27 an arrangement was made with the Edmonton Main Sewage Treatment Plant to have the staff take samples during overflow periods (see description of Edmonton Sewers and Sewage Treatment - Appendix F). The overflow was recorded at this plant but only for rates less than 48 mgd.

Samples were taken at the plant's influent sampling

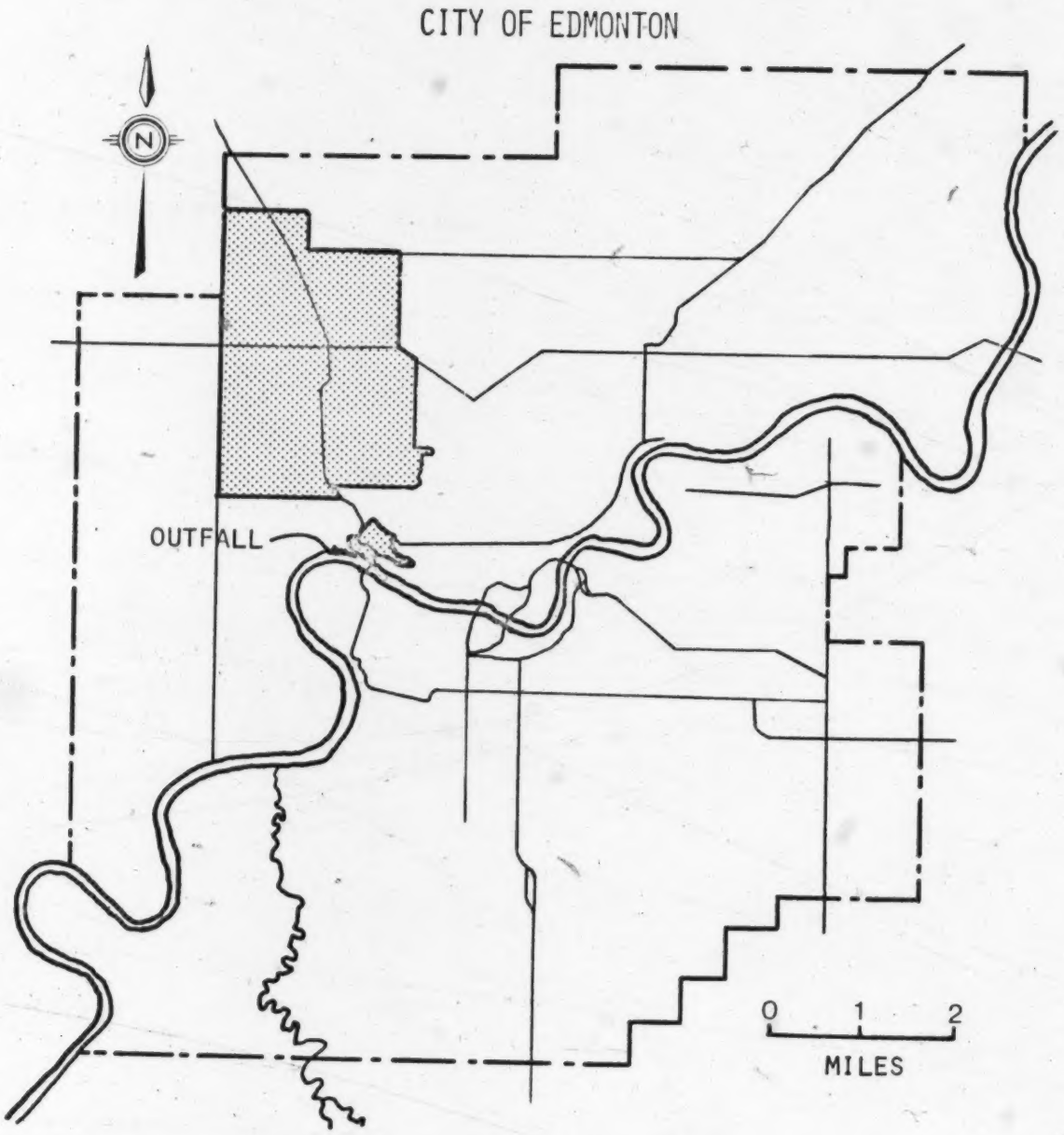
site. This consisted of three taps from the top, middle and bottom of the channel between the grit chambers and the primary treatment units. Each sample was a composite from the three taps. It was assumed that the water entering primary treatment was of the same quality as that by-passed except for the larger material such as rocks, sticks and rags which would be taken out in the grit chambers.

III-3 Stormwater Sampling

Urban runoff was sampled from the flume in Government House Park (situated on the north side of the North Saskatchewan River, west of the Groat Road). The flume is a concrete, rectangular channel 10 feet wide and between five and seven feet deep. The mean slope is 0.0386 feet per foot and there is a slight horizontal curve near the outfall. The flume receives stormwater from a 78 inch storm drain serving the 3185 acre (residential and light industrial) area indicated in FIGURE 1 and a 21 inch drain serving the park and Victoria Park Road.

Samples were taken manually at the outfall of the flume in 64 ounce bottles. The samples were tested within 12 hours of the end of the sampling period.

To determine discharge, velocities were obtained by dumping light floating material (e.g. paper balls) into the flow and recording the time required to pass between two construction joints (55 feet apart). Each recorded velocity was



AREA DRAINING TO GOVERNMENT HOUSE PARK OUTFALL

FIGURE 1

the mean of three to five of these tests. The depth was taken by inserting a ruler into the flow and recording the mean depth. A scale marked on the side of the flume was used when the velocities were too great to permit inserting the ruler. The surface velocity was assumed to be 1.1 times greater than the mean velocity. The discharge was assumed to be the product of the velocity obtained and the cross-sectional area. FIGURE 4 was the stage discharge curve obtained. Once this stage discharge curve was obtained only the depth of flow was measured.

III-4 Studies on the North Saskatchewan River

Along with measuring the pollutants entering the river, attempts were made to determine the effect of the pollutants on the river.

The Fort Saskatchewan Bridge located 19.2 miles downstream from the main sewage treatment plant and 26.4 miles downstream from the Government House Park outfall was chosen as a sampling site.

It was questionable if 19.2 miles was a signficant length of river to obtain complete mixing of combined sewage overflow throughout the flow. In late May and early June the sewage lagoons located north east of Edmonton were discharging the wastewater accumulated during the winter. Since the lagoons were used principally to serve the three meat processing

plants in northeast Edmonton the salt content was very high (Cl = 470 mg/l). Using this opportunity, a series of integrated (surface to bottom to surface) samples were taken of the river water at four cross-sections over a 3.5 mile length of river downstream from the point of discharge from the lagoons. The samples were analyzed for chloride content. The results are presented in Chapter IV.

The velocity of the river was another factor which had to be known so that samples of the river water containing combined sewer overflow and urban runoff could be obtained at the Fort Saskatchewan Bridge. There was no definite source of this information; however after arranging data from the Alberta Research Council and the Civil Engineering Department plots of travel time versus discharge and mean depth versus discharge were obtained (FIGURES 2 & 3). Most of the information was for the river through Edmonton and since this stretch of river is similar to the reach immediately downstream it was felt to be applicable. This was not intended to be a serious study of the discharge characteristics of the river but to be used to determine sampling times and for the discussion in Chapter IV.

On May 25 samples were taken below the Groat Bridge at the beginning of the storm and later below the Fort Saskatchewan Bridge to determine if contamination could be detected. The samples were tested for ammonia since this is a common indication of pollution. The samples varied randomly and gave no indication of a peak concentration.

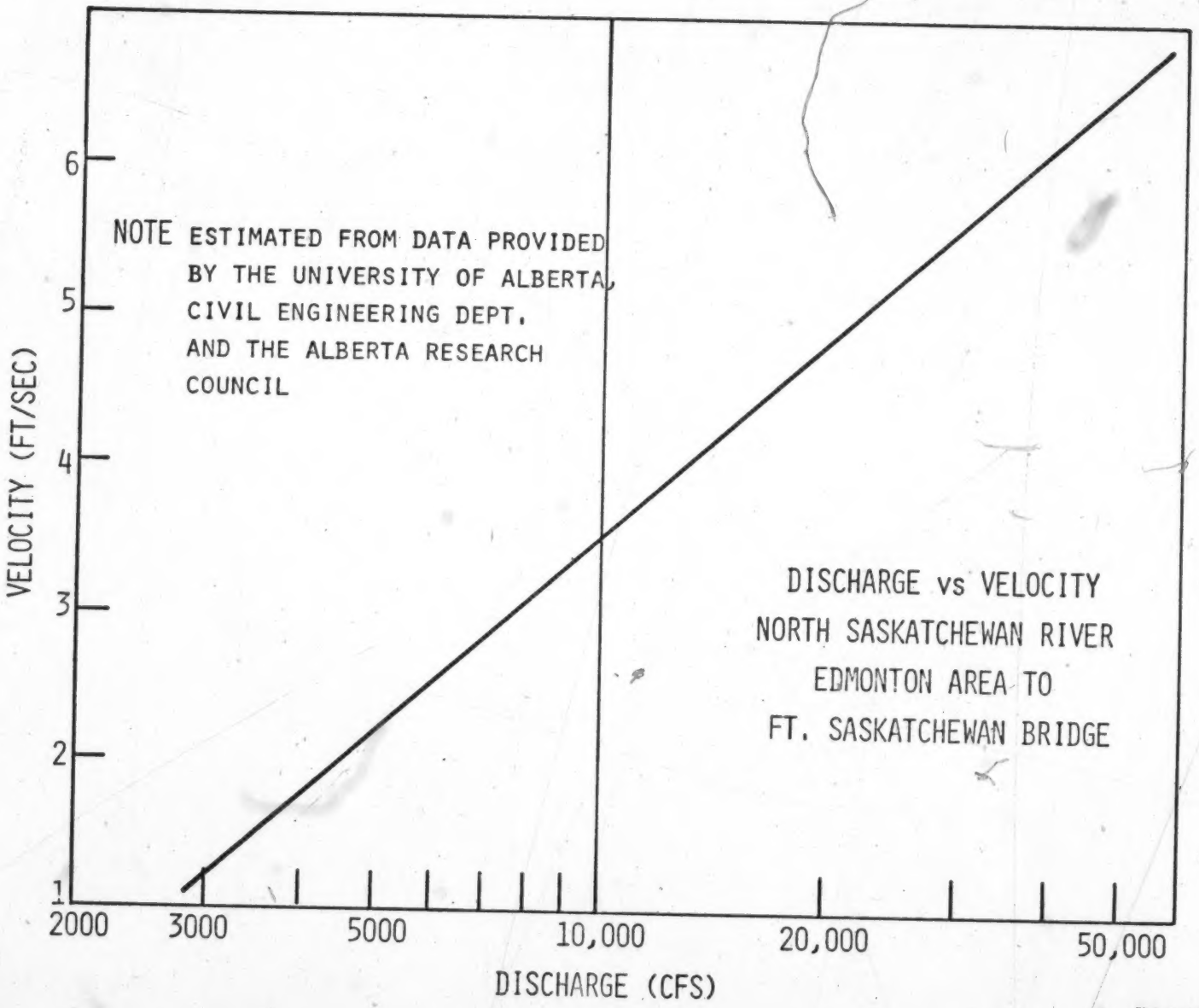

NOTE ESTIMATED FROM DATA PROVIDED BY THE UNIVERSITY OF ALBERTA, CIVIL ENGINEERING DEPT. AND THE ALBERTA RESEARCH COUNCIL
DISCHARGE vs VELOCITY
NORTH SASKATCHEWAN RIVER
EDMONTON AREA TO
FT. SASKATCHEWAN BRIDGE
VELOCITY (FT/SEC)
1
2
3
4
5
6
2000
3000
5000
10,000
20,000
50,000
DISCHARGE (CFS)

FIGURE 2

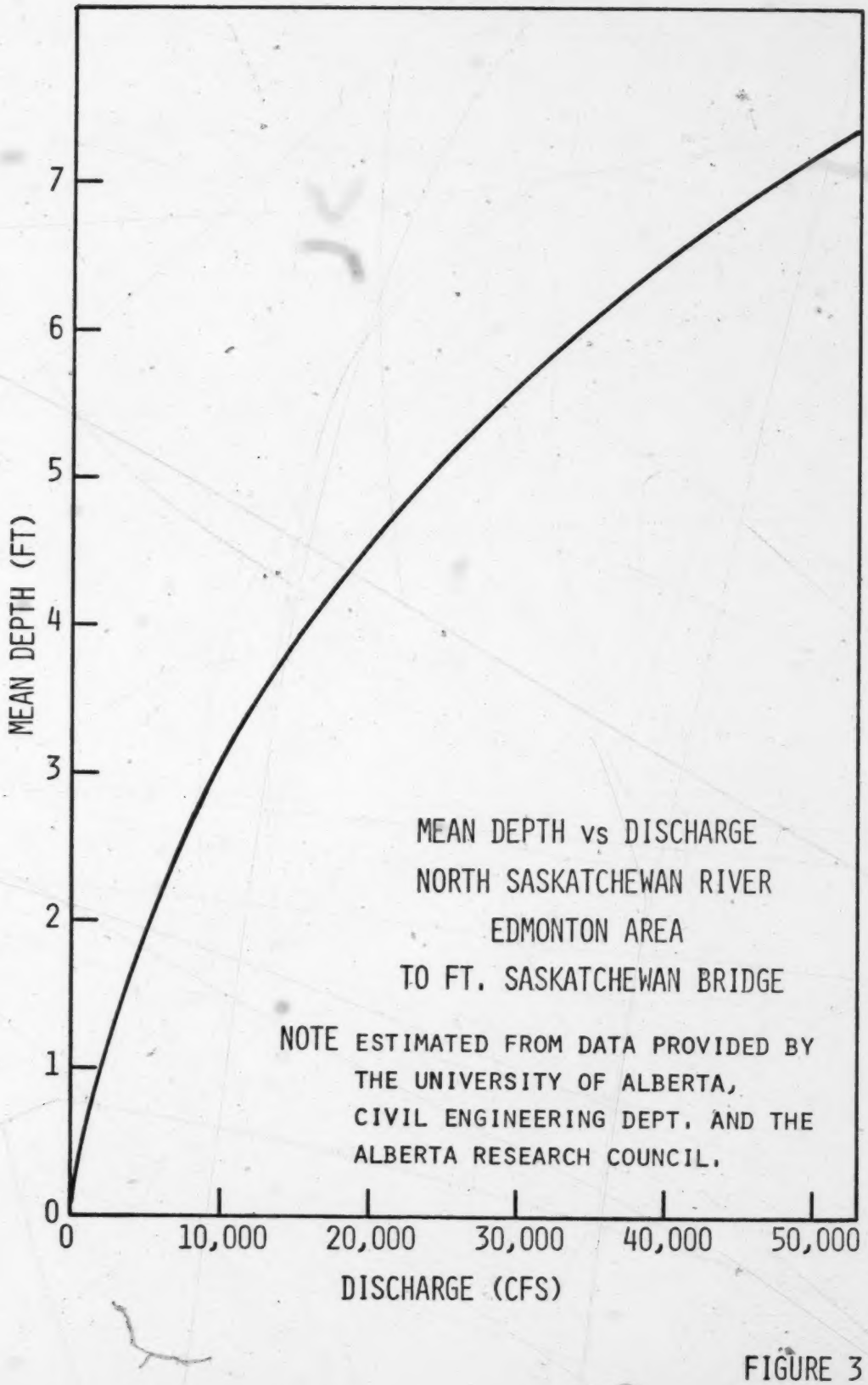

MEAN DEPTH (FT)
0
1
2
3
4
5
6
7
0
10,000
20,000
30,000
40,000
50,000
DISCHARGE (CFS)
MEAN DEPTH vs DISCHARGE
NORTH SASKATCHEWAN RIVER
EDMONTON AREA
TO FT. SASKATCHEWAN BRIDGE
NOTE ESTIMATED FROM DATA PROVIDED BY
THE UNIVERSITY OF ALBERTA,
CIVIL ENGINEERING DEPT. AND THE
ALBERTA RESEARCH COUNCIL.

FIGURE 3

On June 23-24 and June 29 attempts were made to determine the effects of stormwater and combined sewer overflow on the river. Samples were taken from mid-stream off the Fort Saskatchewan Bridge using a DO-BOD sampler similar to that recommended in reference (16). Samples were obtained for DO, BOD-5-20, and solids analyses.

For this study, river flows were obtained from the Federal Water Resources Branch recording station below the Low Level Bridge in Edmonton.

III-5 Rainfall

Rainfall was recorded at the Edmonton Industrial Airport, the University farm near Ellerslie, the University and City Hall. Both the airport and Ellerslie installations had standardized tipping bucket recorders; the airport's was maintained by the Department of Transport, while Ellerslie's was operated by the University. The rain gauges at City Hall and the University were automatic recording rain gauges but were not standardized nor properly located.

The rain gauges were too far apart to represent the true rainfall pattern in the area studies. Attempts were made to evaluate the total rainfall on the city using the Thiessen polygon method; however, the results were to inconclusive to be used.

Rainfall records were obtained from the University library and the Department of Transport for calculations and runoff estimations. The daily rainfall records were used since records of individual storms were not available. The recorded rainfall for May, June, July, August and September for the past 15 year (1954-68) was used for this study.

III-6 Runoff from Snow Melt

Samples of runoff from melting snow were obtained from the Government House Park Flume. Samples were taken as often as four times a day during the early part of the runoff period. These samples were analyzed for chloride ion content and suspended solids.

At the author's request samples were collected from the North Saskatchewan River once a day during March and April at the Devon Water Treatment Plant (approximately 22 miles upstream of Edmonton) by the plant operator. These samples were analyzed for chloride ion and suspended solids.

All further information used in this study was obtained from the Department of the Environment and the City of Edmonton.

III-7 Testing

All testing was conducted in accordance with methods outlined in the twelfth edition (1965) of "Standard Methods for the Examination of Water and Wastewater" (16).

Where more than one method is outlined the specific test used is given below. Also given is any deviation from the method outlined, difficulties encountered with tests and information which may clarify the procedure.

Biochemical Oxygen Demand (BOD-5-20) - "Azide Modification of Iodometric Method" (Winkler) or Dropping Mercury Apparatus (not described in "Standard Methods" - an electrical apparatus owned by the Department of Health).

Samples of stormwater taken during May were seeded with one of two drops of fresh sewage but this practice was discontinued upon the advice of the Department of Health chemists. There was no correction for seeding.

All BOD-5-20 tests commenced within 12 hours of the taking of the last sample (most were started immediately). Samples were stored in a cold storage room (3°C) prior to testing.

Chlorides - "Argentometric Method" or "Mercuric Nitrate Method".

Parallel testing to determine the more desirable method showed no noticeable difference between the two except for river water which had a very low chloride content, in which case the end point of the "Mercuric Nitrate Method" was more readily recognized.

Nitrates - "Brucine Method"

Ammonia - "Direct Nesslerization Method"

Hardness - "EDTA Titrimetric Method" - "Univer" (total hardness) and "Calvar" (calcium hardness) were used in place of the biffer and indicator.

Sulphates - "SulfaVer" (trade name - HACH Chemical Company) was used in place of barium chloride and the conditioning reagent.

Samples for pesticides and herbicides were obtained for the Department of Health at their request. The analysis was performed by the staff of the Environmental Health Services Laboratory by extraction, separation and identification by a gas chromatograph.

Tests requiring rating curves were performed with the Department of Health's equipment so that their rating curves could be used to determine concentrations.

CHAPTER IV

DISCUSSION OF RESULTS

IV-1 Determination of Runoff Flows

In order to determine the flow from the storm sewer outfall at Government House Park, a stage-discharge curve was developed from the measurement of the depth of flow and the surface velocity. The surface velocity of flow in an open channel will normall vary from 1.1 to 1.2 times the mean velocity. In this case a correction of the 1.1 was used because of the relatively shallow depths (maximum 10") experienced. FIGURE 4 is the resulting stage-discharge curve.

To check the stage-discharge curve, Manning's Formula was used to determine the theoretical curve for the flow.

$$Q = \frac{1.486\ AR^{2/3}\ S^{1/2}}{n} \qquad (1)$$

In this formula Q is the discharge, A is the cross-sectional area, R is the hydraulic radius or the area divided by the wetted perimeter, S is the slope of the channel and n, the co-efficient of roughness which for smooth concrete surfaces is approximately equal to 0.011 to 0.012.

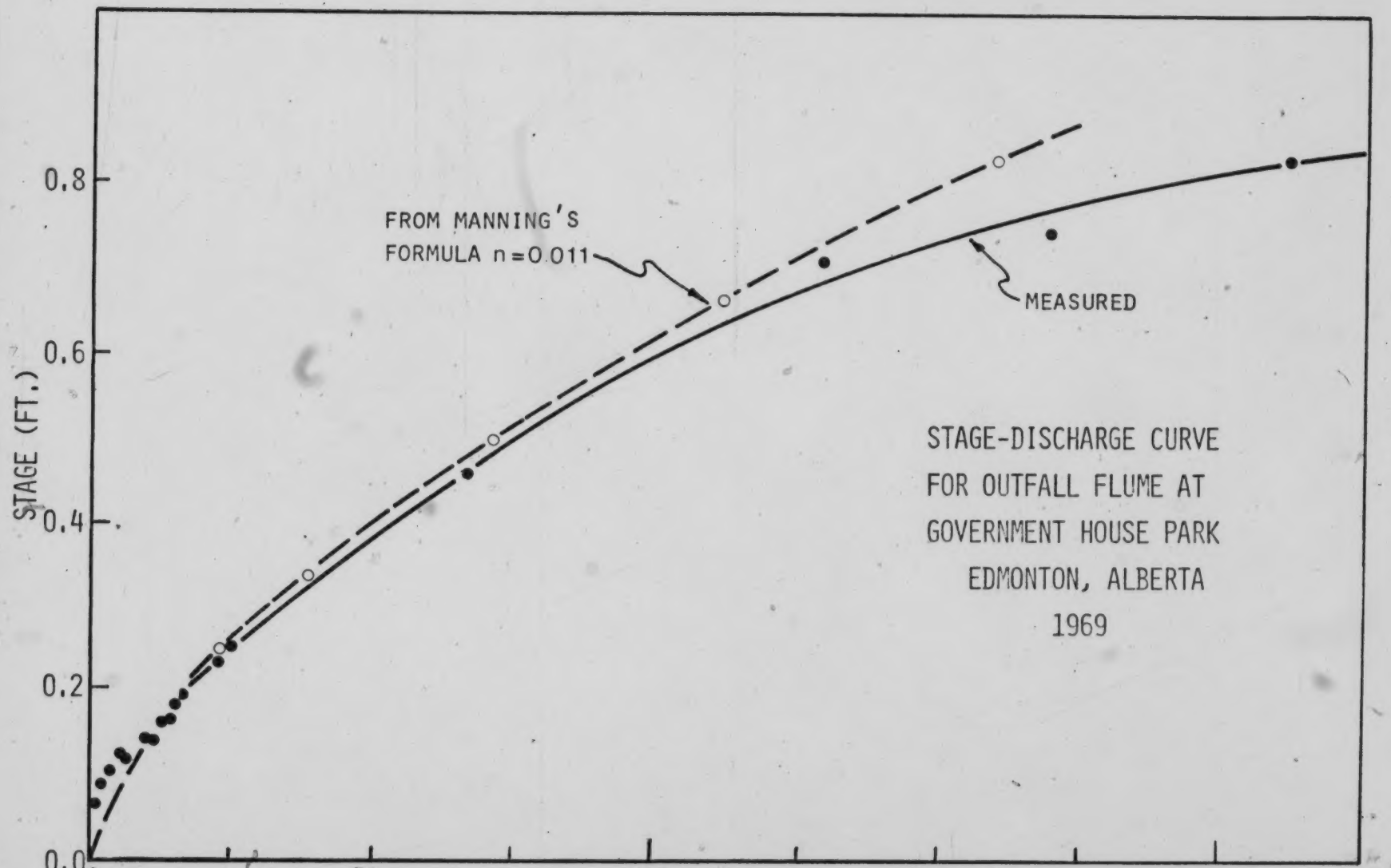

FROM MANNING'S
FORMULA n=0.011
MEASURED
STAGE-DISCHARGE CURVE
FOR OUTFALL FLUME AT
GOVERNMENT HOUSE PARK
EDMONTON, ALBERTA
1969
STAGE (FT.)
0.0
0.2
0.4
0.6
0.8
0
50
100
150
200
DISCHARGE (CFS)

FIGURE 4

The slope was surveyed and found to be 0.0386 feet per foot. Using this slope and a n value of 0.011, the resulting stage discharge curve showed excellent correlation with that measured up to 120 cfs. Only for the highest values recorded was there any significant variation. The flow values measured are therfore felt to be representative to the actual flows.

IV-2 Rainfall During Study

The total amount of rainfall recorded for the various storms studies is presented in TABLE I. As mentioned in Chapter III, the gauges at the University Campus and the City Hall were not properly located and accuracy would depend on wind conditions. Of particular note is the variation of the afternoon storm of June 6, 1969. It appears to be concentrated around the University area. This would mean that the intense rainfall would be concentrated in the steeper areas of the drainage basin that discharges at Government House Park and thus the runoff would not be representative of the entire drainage basin. This could explain why the loading from this storm varied so greatly from others in FIGURE 12.

A summary of the most common methods used in determining urban runoff for the design of storm sewer systems is given in Appendix H. The total runoff measured at Government House Park was plotted against the total rainfall in FIGURE 5.

TABLE I

RAINFALL DURING STUDY PERIOD

Date 1969	Recorder Rainfall (in)			
	Industrial Airport	City Hall	University Campus	University Ellerslie
May 13	0.02	0.05	0.04	0.08
May 14	0.11	0.04	0.06	0.01
May 25	0.32	0.43	0.32	0.14
May 27	0.30	NR	0.06	----
May 27	0.8	0.08	0.06	0.02
May 29	0.32	0.11	0.04	0.07
May 30	0.13	0.18	0.06	0.29
June 6	0.18	NR	0.22	0.25
June 6	0.09	NR	0.50	----
June 23	0.28	NR	0.22	0.13
June 28	0.25	NR	0.34	0.32
June 29	0.10	0.64	0.20	0.20
July 8	0.01	0.01	0.01	0.09
July 16	0.29	NR	0.28	0.55

NR - Not Recorded

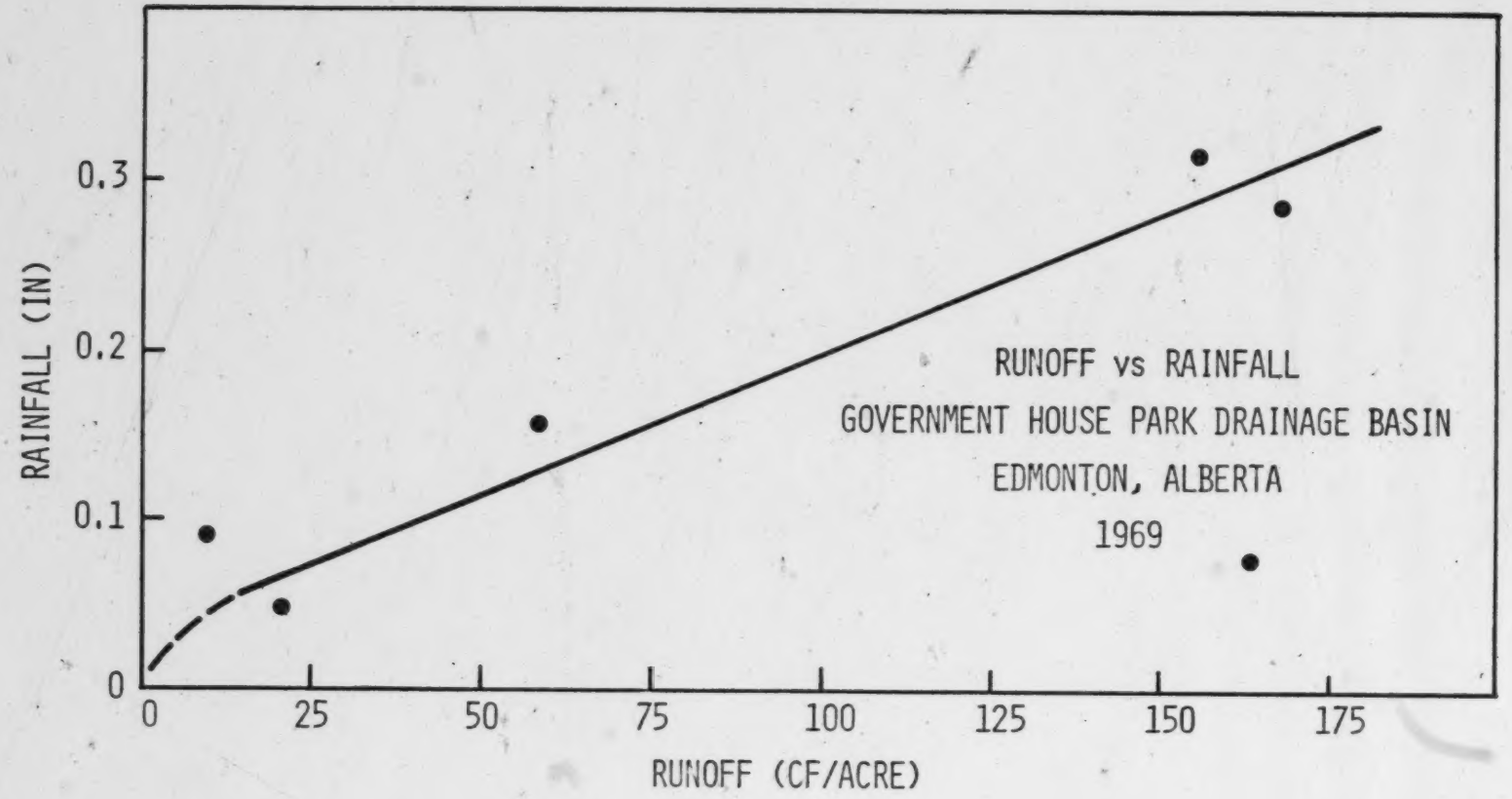

RUNOFF vs RAINFALL
GOVERNMENT HOUSE PARK DRAINAGE BASIN
EDMONTON, ALBERTA
1969
RAINFALL (IN)
0
0.1
0.2
0.3
0
25
50
75
100
125
150
175
RUNOFF (CF/ACRE)

FIGURE 5

Using the rational formula, the total mean runoff coefficient for these storms is 0.145. This is considerably less than the 0.40 that a designer would use for an area of this nature; however, all the storms were light compared to the five year design storm and since the coefficient varies somewhat with the intensity of the storm, the figure appears reasonable.

The number of days for which a given total rainfall can be expected is presented in TABLE II to illustrate the rainfall intensity expected during the summer.

IV-3 Diffusion Length of the River

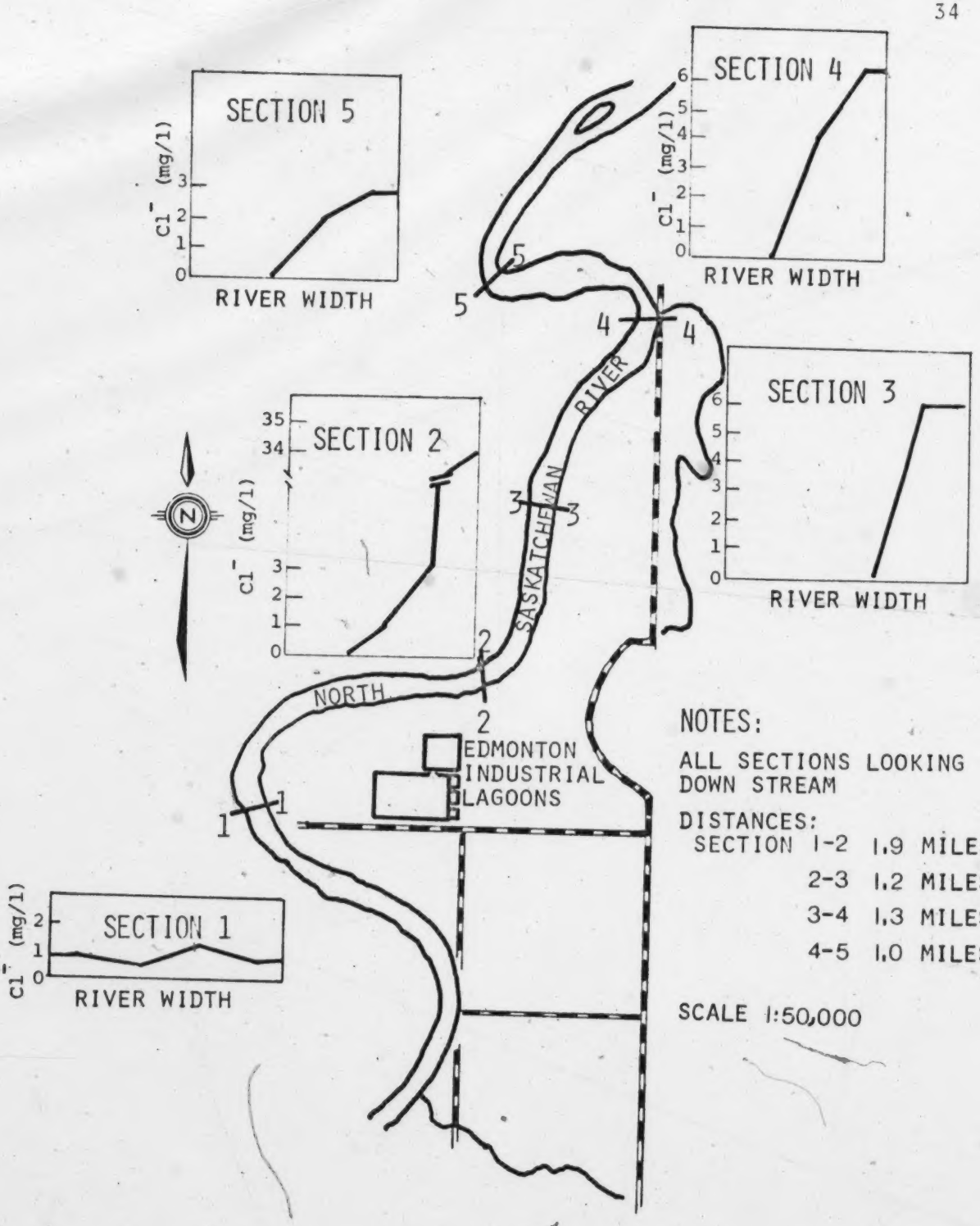
FIGURE 6 illustrated the findings for the diffusion of the effluent from the Edmonton sewage lagoons for 3.5 miles downstream of the outfall. The four or five samples taken at each section were intended to be equally spaced, however, the locations were estimated rather than measured. The locations of the sections are fairly accurate since they are associated with landmarks. In FIGURE 6 the width of the graphs is proportional to the widths of the sections.

The first section samples was upstream of the outfall and had a low uniform chloride content of between 0.5 and 1.0 mg/l. The second section taken just below the outfall started at 34 mg/l on the right bank and then dropped to zero at approximately the middle of the river. Sections 5 and 5 showed concentrations of 6 and 7 mg/l respectively at the right

TABLE II

AVERAGE DAYS OF RAINFALL - EDMONTON

Rainfall (in)	Number of Days of Rainfall				
	May	June	July	August	September
0.01 - 0.05	3.8	4.3	3.5	3.3	4.0
0.06 - 0.10	1.3	2.3	2.0	2.4	1.6
0.11 - 0.20	1.0	1.9	2.3	2.3	1.9
0.21 - 0.30	1.0	1.7	1.1	1.1	0.7
0.31 - 0.50	0.6	0.7	1.5	1.3	0.5
0.51 - 1.0	0.8	1.1	1.0	1.1	0.4
1.0 +	0	0.4	0.6	0.7	0.2



STUDY OF THE DIFFUSION LENGTH OF THE NORTH SASKATCHEWAN RIVER
JUNE 2, 1969

FIGURE 6

bank dropping to zero at the middle of the river. By section 5 the concentration had dropped to 3 mg/l at the right side and appeared more uniformly distributed over the right half of the section.

From the above, it was concluded that the 19.2 miles between the City of Edmonton main sewage treatment plant (this is the location of the last combined overflow) and the Fort Saskatchewan Bridge would be adequate for mixing, considering that there are six bends in this stretch of river as compared to one in the stretch studied. This conclusion was later confirmed by Pospisilik(27) in his studies of diffusion in the river during 1971 and 1972.

IV-4 Urban Runoff from Snowmelt

The analysis of snowmelt samples taken specifically for this study are presented in TABLE B1. The chloride content was analyzed to determine if the 4,000,000 pounds of salt used on the city streets during the winter seasons had any serious effect on the chloride content of the river. It was also used as an indication of the variation of the dissolved solids in in runoff during the melting period. The chloride content of the samples taken varied between 11 mg/l and 400 mg/l, with variations of this magnitude being experienced in a single 24 hour period. FIGURES 7 and 8 show the variation of the chloride content and the suspended solids content with time. Where sufficient samples were taken close enough together, they have been

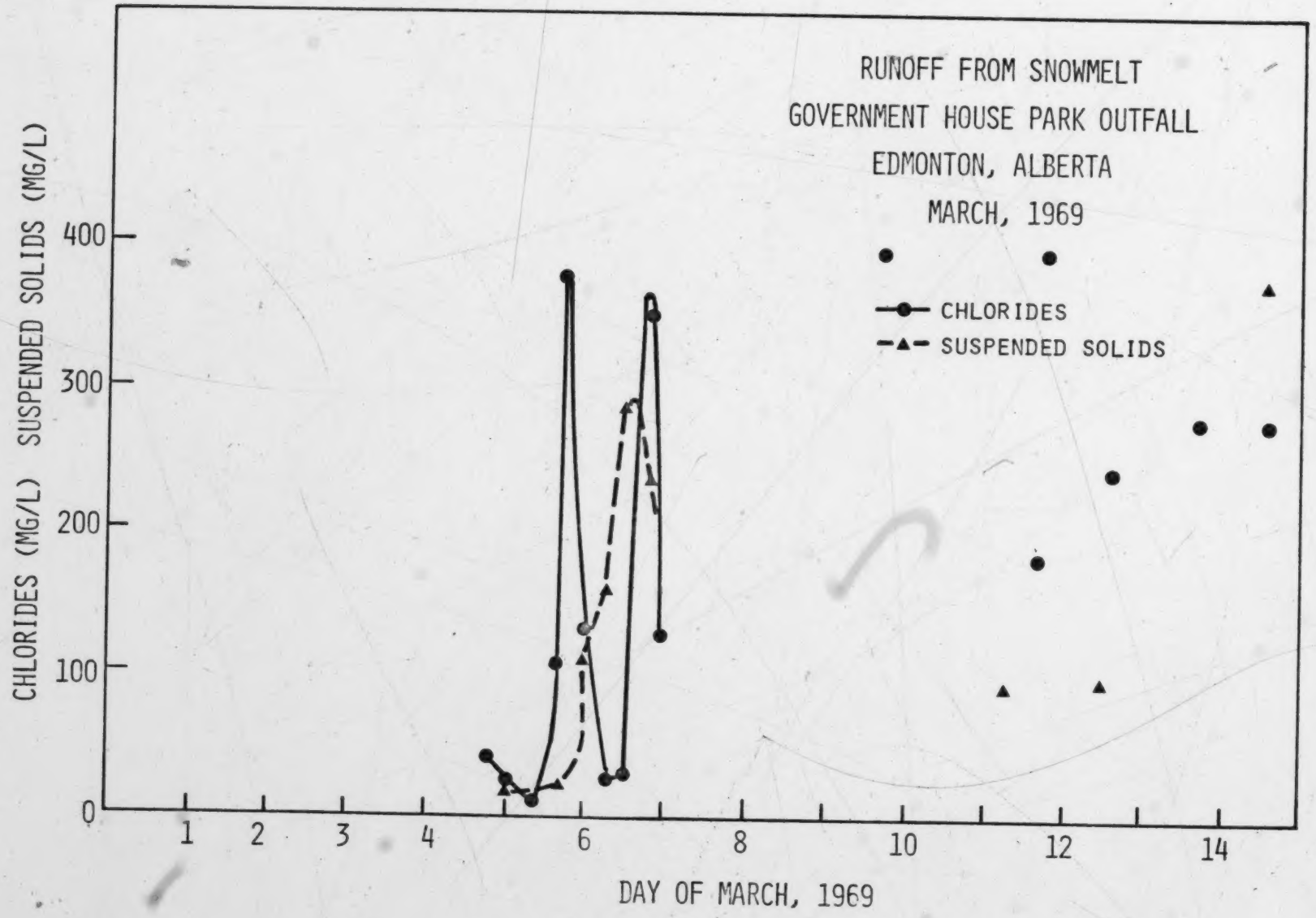

RUNOFF FROM SNOWMELT
GOVERNMENT HOUSE PARK OUTFALL
EDMONTON, ALBERTA
MARCH, 1969
CHLORIDES
SUSPENDED SOLIDS
CHLORIDES (MG/L) SUSPENDED SOLIDS (MG/L)
0
100
200
300
400
1
2
3
4
6
8
10
12
14
DAY OF MARCH, 1969

FIGURE 7

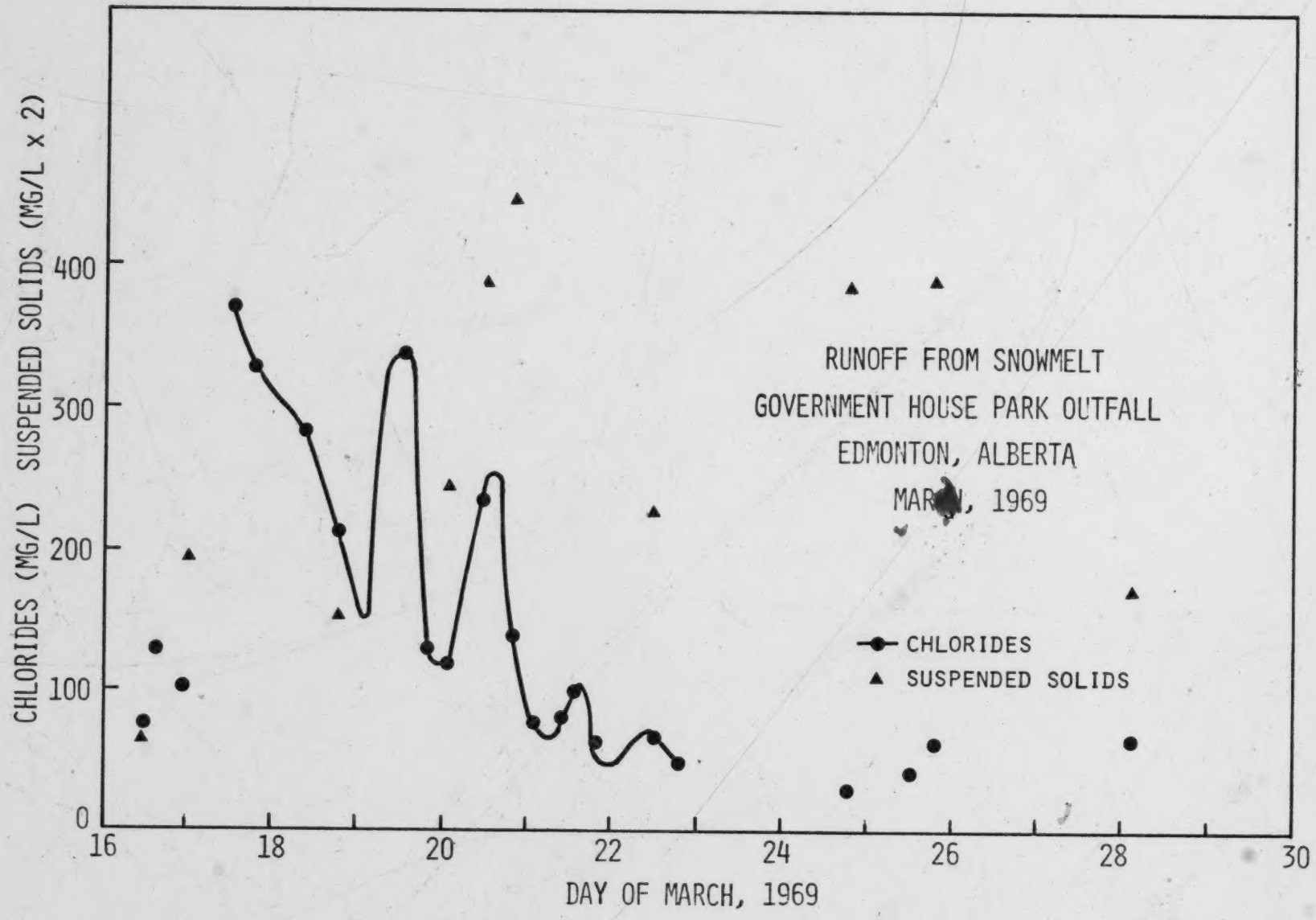

CHLORIDES (MG/L) SUSPENDED SOLIDS (MG/L x 2)
0
100
200
300
400
16
18
20
22
24
26
28
30
DAY OF MARCH, 1969
RUNOFF FROM SNOWMELT
GOVERNMENT HOUSE PARK OUTFALL
EDMONTON, ALBERTA
MARCH, 1969
CHLORIDES
SUSPENDED SOLIDS

FIGURE 8

plotted to illustrate the diurnal variation. It should be noted that during the early part of March, the flows would drop off to almost zero by early morning. However, by mid-March, there was a substantial flow throughout the entire day.

During the early stages of the runoff period, the chloride content of snowmelt would rise rapidly in the afternoon, peak at about 1700 to 1800 hours and then drop off rapidly. Thus the peak chloride content corresponded roughly with the peak melting period allowing for the lag time in the sewer. This was contrary to what was expected since it was felt that snow with a high chloride content would melt at the lower temperatures during the morning and late afternoon, thus the chloride content would be higher since there would be no dilution from snowmelt with a low chloride content.

As the melting period progressed, the peak period of chloride content in the runoff shifted to between 1100 to 1400 hours.

The suspended solids content of the snowmelt also appeared to vary sharply throughout the day; however, the peak did not coincide with that of the chloride content. The suspended solids varied from 22 mg/l to 876 mg/l. In general, the suspended solids from snowmelt were considerably less than that found in runoff from rain storms. The solids were mostly silt and colloidal material and there was very little evidence of

the 50,000 cubic yard of sand (approximately 13.5 million pounds) the City used in their street sanding operation during the winter. It must be assumed that most of the sand is either hauled to the river during snow clearing operations or remains to be picked up during the spring street sweeping program.

From March 11 to April 28, 1969, 48 samples of river water were taken upstream of Edmonton at Devon. Also 148 samples were taken downstream at the Sherritt Gordon Mines water intake from January to May 31, 1969. The mean monthly chloride content of the samples are present in TABLE III.

TABLE III

CHLORIDE CONTENT IN THE NORTH SASKATCHEWAN RIVER

Month	Mean Upstream Of Edmonton (Devon)	Mean Downstream Of Edmonton (Sherritt Gordon)
January	---	4.3
February	---	5.7
March	0.5	7.4
April	1.3	5.1
May	0	3.8

The higher chloride content downstream of Edmonton is the result of sanitary and industrial effluents and will vary depending on the degree of dilution provided by the river.

For the month of March, which encompassed almost the entire runoff period from snowmelt, the mean chloride content increased by 1.5 - 2.5 mg/1. Using the mean flow for March (3260 cfs), an increase of 2.5 mg/1 would represent 1.36 million pounds of chloride or 2.2 million pounds of the 4 million pounds of salt used on the road.

Since 1969, the Alberta Department of the Environment has been sampling and testing street runoff during the snowmelt period. An accumulation of this data both published and unpublished is presented in Appendix B. These surveys dealt almost exclusively with separate sewers. There is only one sample definitely taken from a combined overflow (TABLE B15). The analyses of runoff quality from separate sewers during 1969 and 1972 is presented in TABLES B2 to B5. The procedure for sampling and the time of day of sampling is not known. In 1973, the Department conducted a fairly thorough investigation of the runoff from February 22 to March 29. Thirty-three samples were taken between 1400 and 1600 hours. at nine different outfalls. TABLE IV summarized the results while detailed analyses are presented in TABLES B6 to B14.

Some of the parameters of particular interest were the chlorides which ranged up to 698 mg/1 and averaged 181 mg/1, nitrates and nitrites were as high as 19.0 mg/1 and averaged 2.5 mg/1, ammonia was as high as 18.0 mg/1 and averaged 2.2 mg/1, BOD as high as 200 mg/1 averaging 26 mg/1, COD to

TABLE IV

ANALYSIS OF RUNOFF FROM SNOWMELT

EDMONTON, 1974

PARAMETER	MEAN	LOW	HIGH
pH	7.3	6.9	8.2
Specific Conductance (umho/cm)	1034	360	2300
Hardness, Total (Mg/l)	234	86	450
Alkalinity (Mg/l)	138	65	302
Sulfate (Mg/l)	175	33	450
Chloride (Mg/l)	157	26	698
Nitrate & Nitrite (Mg/l)	2.94	.20	19.00
Iron, Total (Mg/l)	2.7	0.1	23.0
Calcium (Mg/l)	61.0	28	140
Magnesium (Mg/l)	19.8	3.0	99.0
Sodium (Mg/l)	126.4	18.0	470.0
Potassium (Mg/l)	10.9	2.0	45.0
Phosphate (Mg/l)	2.7	0.8	10.4
Ammonia - N (Mg/l)	2.19	0.28	18.00
Biochemical Oxygen Demand (Mg/l)	26.1	0.1	200.0
Chemical Oxygen Demand (Mg/l)	154.2	10.0	355.0
Oil and Grease (Mg/l)	6.0	1.0	18.0
Phenols (Mg/l)	.039	0.001	1.000
Threshold Odour Number	8.1	1.0	32.0
Turbidity	15.0	15.0	15.0
Total Solids (Mg/l)	1097.3	186.2	2400.0
Non-filtrable Residue (Mg/l)	399.8	36.0	1210.0
Cobalt (Mg/l)	0.021	0.001	0.062
Copper (Mg/l)	0.022	0.001	0.062
Manganese (Mg/l)	0.473	0.020	1.620
Nickel (Mg/l)	0.073	0.008	0.320
Cadmium (Mg/l)	0.003	0.001	0.026
Chromium (Mg/l)	0.029	0.005	0.067
Lead (Mg/l)	0.101	0.002	0.455
Mercury (Mg/l)	0.0006	0.0005	0.0050
Nitrite (Mg/l)	0.30	0.05	2.30
Hydrocarbons (Mg/l)	0.001	0.001	0.001
Benzo-a-Pyrene (Mg/l)	0.001	0.001	0.001
Dissolved Oxygen (Mg/l)	23.5	0.01	68.0
Total Dissolved Solids	760.0	520.0	970.0
Colour - Filter #1	96.00	86.00	99.00
Filter #2	94.33	87.00	98.00
Filter #3	85.19	64.00	96.00

330 mg/l averaging 145 mg/l. Oils and greases were up to 18.0 mg/l and averaged 5.9 mg/l, total solids to 2400 mg/l averaging 1110 mg/l and suspended solids were to 1210 mg/l and averaged 386 mg/l. It should be noted that all of the above values, with the possible exception of the nitrogen compounds, equal or exceed values that would be expected in the effluent of a normal secondary sewage treatment plant.

The sample of combined sewer overflow equals or exceeds the strength of normal raw sewage.

The Department of the Environment also sampled the North Saskatchewan River at the Quesnell Bridge at the west end of the City and at the Capilano Bridge near the east end of the City in an attempt to determine the effect of runoff on the River as it passes through the City. Extensive analyses were performed on the samples including analyses for many of the heavy metals. TABLE V summarizes some of the parameters of general interest in water pollution studies. Each value presented in the table represents the mean of three samples taken over the cross-section of the river.

The snowmelt runoff period during 1973 lasted to approximately the end of March. During this period, chlorides, ammonia, BOD-5-20, total solids and chromium showed a general increase while the nitrites and nitrates, oils and greases, and phenols varied randomly. From March 16, 1973 to March 29,

TABLE V

WATER QUALITY - NORTH SASKATCHEWAN RIVER - EDMONTON

March & April 1973

Date & Place	Chlorides mg/l	NO_2 & NO_3 mg/l	Ammonia mg/l	BOD mg/l	Oils & Grease mg/l	Phenols mg/l	Total Solids mg/l	Chromium mg/l
March 16, 1973								
Quesnell Br.	2	0.5	.02	0.7	2.8	0.001	239	0.002
Capilano Br.	4	0.1	.2	1.1	2.5	0.001	263	0.004
March 20, 1973								
Quesnell Br.	5	0.7	0.41	1.8	1.8	0.001	219	0.007
Capilano Br.	10	0.3	1.7	1.0	1.0	0.001	228	0.008
March 22, 1973								
Quesnell Br.	1	0.2	0.2	0.5	1.3	0.001	221	0.014
Capilano Br.	1	0.2	0.2	1.5	2.5	0.001	253	0.012
March 27, 1973								
Quesnell Br.	3	0.4	0.2	0.1	1	0.002	221	0.0[illegible]
Capilano Br.	5	0.6	0.2	0.5	1	0.001	253	0.0[illegible]
March 29, 1973								
Quesnell Br.	5	0.3	1.0	1.1	3.3	0.003	299	0.002
Capilano Br.	7	0.5	0.4	1.2	2.8	0.004	280	0.006
April 3, 1973								
Quesnell Br.	2.0	0.7	0.6	3.5	1.1	0.004	353	0.006
Capilano Br.	2.7	0.6	0.6	3.1	1.0	0.004	328	0.010
April 5, 1973								
Quesnell Br.	2.9	1.0	0.2	3.9	1	0.008	262	0.002
Capilano Br.	3.3	1.0	0.2	4.3	1	0.013	313	0.003
April 10, 1973								
Quesnell Br.	2	0.7	0.2	1.2	1	0.004	250	0.004
Capilano Br.	3	1.5	0.2	2.7	1	0.005	234	0.005
April 12, 1973								
Quesnell Br.	2	1.9	0.9	2.0	1	0.003	387	0.21
Capilano Br.	4	1.4	0.3	2.4	2	0.002	316	0.17

1973, the mean river flow at Edmonton averaged 3920 cfs. At this flow a one part per million increase in any parameter, if it was consistent throughout the day, would equal approximately 18,000 pounds of the particular contaminant.

It should be noted that the runoff during the spring of 1973 was light with only 6 inches of standing snow recorded at the Industrial Airport at the start of the melt period. In comparison, during 1969 there was 17 inches of snow at the start of runoff.

Because of the low flows during 1973 runoff period, there was seldom any overflow from the combined sewers. The main sewage treatment plant by-passed the primary clarifiers on only four occasions during March as compared to 17 times during March of 1972. The Department of the Environment checked the overflows at the Dawson Bridge and south west of the Capilano Bridge. At the Capilano Bridge, occasional overflow was observed. Five samples were taken at this location, but unfortunately due to the piping configuration, they were a mixture of combined sewer overflow and runoff from a separate sewered area. The samples were not representative of runoff through a combined system, and are not presented in this report.

Although it appeared that the runoff from the separate sewer system had little significant effect on the North Saskatchewan River, it was felt that in streams which do not have the great dilution capacity of the river some of the

metals and compounds found in the runoff from snowmelt might have toxic effects on fish found in these streams.

Two areas of particular concern are Fish Creek in Calgary and Whitemud Creek in Edmonton. Fish Creek is a popular fishing stream and supports several different species of trout, while Whitemud Creek has only small "garbage fish" except during the early spring when suckers and pike migrate upstream from the North Saskatchewan River to spawn in the marshy area south of Edmonton. Both creeks are being encroached upon by the cities, with many storm drains already constructed on their banks.

The runoff from these cities occurs three weeks to one month prior to the rural runoff. The flows are very low in both of these creeks during the winter and early spring and the urban runoff is the major flows during this time. Because of this, values of the various contaminants found in runoff from snowmelt from the City of Edmonton could be assumed to be approximately the same as those in the creeks.

Information on toxicity levels tends to be limited and what is available relates to specific tests on specific fish. The toxic effect that any substance will have on fish will vary from one species to another and with the exposure time to the toxicant. Toxicity will also vary with the temperature, pH, alkalinity, and general chemical composition of water being considered. In addition to this, toxicity may

be caused by a combination of metals or compounds which by themselves would not be toxic.

TABLE VI summarizes the metals and compounds which have been found in storm runoff and which may produce toxicity. This table was compiled by Dr. P. Paetkau, Biologist with the Department of the Environment (28), utilizing various studies performed throughout the world. The column titled "Toxicity Levels" refers to the range of limits found to produce a 50% kill of some species of fish in standing water within 96 hours. The column titled "Safe Levels" is the concentration generally accepted as levels at which there will be little or no adverse effects on most species of fish in most waters when they are exposed to these concentrations throughout their life time. The toxicity level and safe levels given in the table should be interpreted as probable values.

From samples taken it would appear that concentrations of lead, zinc, ammonia, copper, and oil & grease in urban runoff exceed the safe levels. Exposure to the concentrations of copper and ammonia listed above could produce kills depending upon the factors mentioned previously. The concentrations of zinc and lead might not be harmful to fully developed fish, but could interfere with spawning or be toxic to developing fish. Oil and greases at 32 mg/l could be toxic but this depends on the type of hydrocarbon (light or refined oils

such as diesel oils are considerably more toxic than the heavier greases).

TABLE VI

TOXICITY LEVELS FOR FISH

	Toxicity Level (mg/l)	Safe Level (mg/l)	Max. Concentration Found in Runoff (mg/l)
Magnesium (nitrate)	400		52
Cadmium	0.2-0.3	0.03	0.026
Chromium (hexavalent)	45	0.02	0.067
Cobalt	10	0.3	0.043
Copper	0.05-0.3	0.05	0.147
Lead (nitrate)	0.1-0.33	0.33	1.34
Manganese	40		1.62
Mercury	0.008-0.01		0.001
Nickel	0.8		0.20
Zinc	0.6-17.0	0.03-0.08	1.01
Phenols	1-10		1.0
Oils & Grease	25		32
Ammonia	25	1.5	18.0

IV-5 Urban Runoff from Rainfall

The results of the analyses performed on samples of runoff from areas services by a separate storm sewer system are presented in TABLES C1 to C7. Most of the results have also been plotted (FIGURES C1 to C6) to illustrate the variation of the BOD-5-20 and solids with flow.

The hydrographs of flows were typical of a runoff hydrograph expected from a large drainage basin. They were fairly

uniform in their development and illustrate the common features of a river hydrograph; that of rising limb, the crest and the recession or depletion curve.

The strength of the BOD-5-20, in general, was high at the start of each storm and decreased as the storm progressed. Only the June 23, 1969 storm showed any significant variation from this pattern. During this storm, the BOD rose and dropped off in a similar manner as the hydrographs. The strength of the samples varied from 108 mg/l to 18 mg/l, averaging 51 mg/l.

The total solids and the total volatile solids in most cases started off high, decreasing as the flow increased, and then tending to rise slightly as the flow dropped off. There did not appear to be any relationship between the BOD-5-20 and the total volatile solids or the volatile suspended solids.

Conductivity tests were performed in order to determine the dissolved solids content of the runoff. This is a common practice in automatic river monitoring since the conductivity reflects the ionic strength of solution. A constant, usually in the range of 0.6 to 0.8 is used to convert the 25 degree Centigrade conductivity reading to a dissolved solids value.

Suspended solids analyses were conducted on the samples taken on June 23, 1969 and July 16, 1969 to deter-

mine this constant. From the results illustrated in FIGURE 9, it does not appear that such a constant exists. This could be the result of varying amounts of dissolved organic compounds which have a low ionic strength in proportion to their weight. These analyses, however, did illustrate that a simple relationship existed between the suspended solids and the total aolids. From FIGURE 10 an approximate value of suspended solids could be obtained from the formula:

$$SS = 0.8\ TS\ mg/l - 250 \qquad (2)$$

This formula should not be interpreted as a method of determining dissolved solids since they comprise only a small percentage of the total solids and slight deviation from the curve in FIGURE 10 would result in very high percentage error in determining the dissolved solids.

For the samples taken on June 16, 1969 more detailed analyses were performed. The chlorides, sulphates, nitrates, and alkalinity were all relatively low and should be of little consequence to the river water quality. Oils and greases varied randomly throughout the runoff period averaging 3.8 mg/l. The Alberta surface water criteria stipulate that oils and greases be "virtually absent". When considering the quantities of runoff involved, a concentration of 3.8 mg/l could be of some significance to the water quality in the river. There were no pesticides found in the runoff and only a small quantity of herbicides (average 11.3 µg/l).

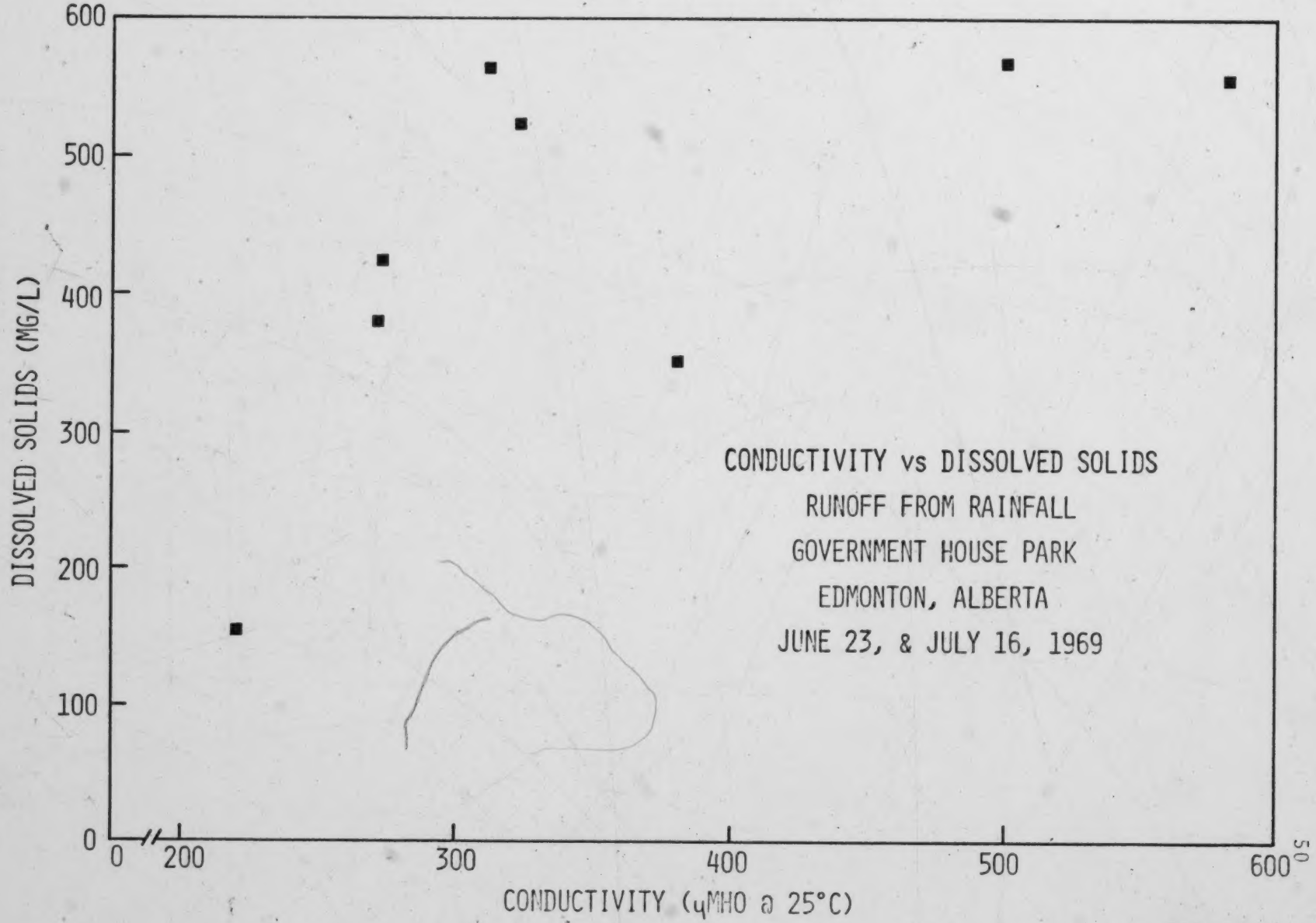

600
500
400
300
200
100
0
DISSOLVED SOLIDS (MG/L)
0
200
300
400
500
600
CONDUCTIVITY (μMHO a 25°C)
CONDUCTIVITY vs DISSOLVED SOLIDS
RUNOFF FROM RAINFALL
GOVERNMENT HOUSE PARK
EDMONTON, ALBERTA
JUNE 23, & JULY 16, 1969

FIGURE 9

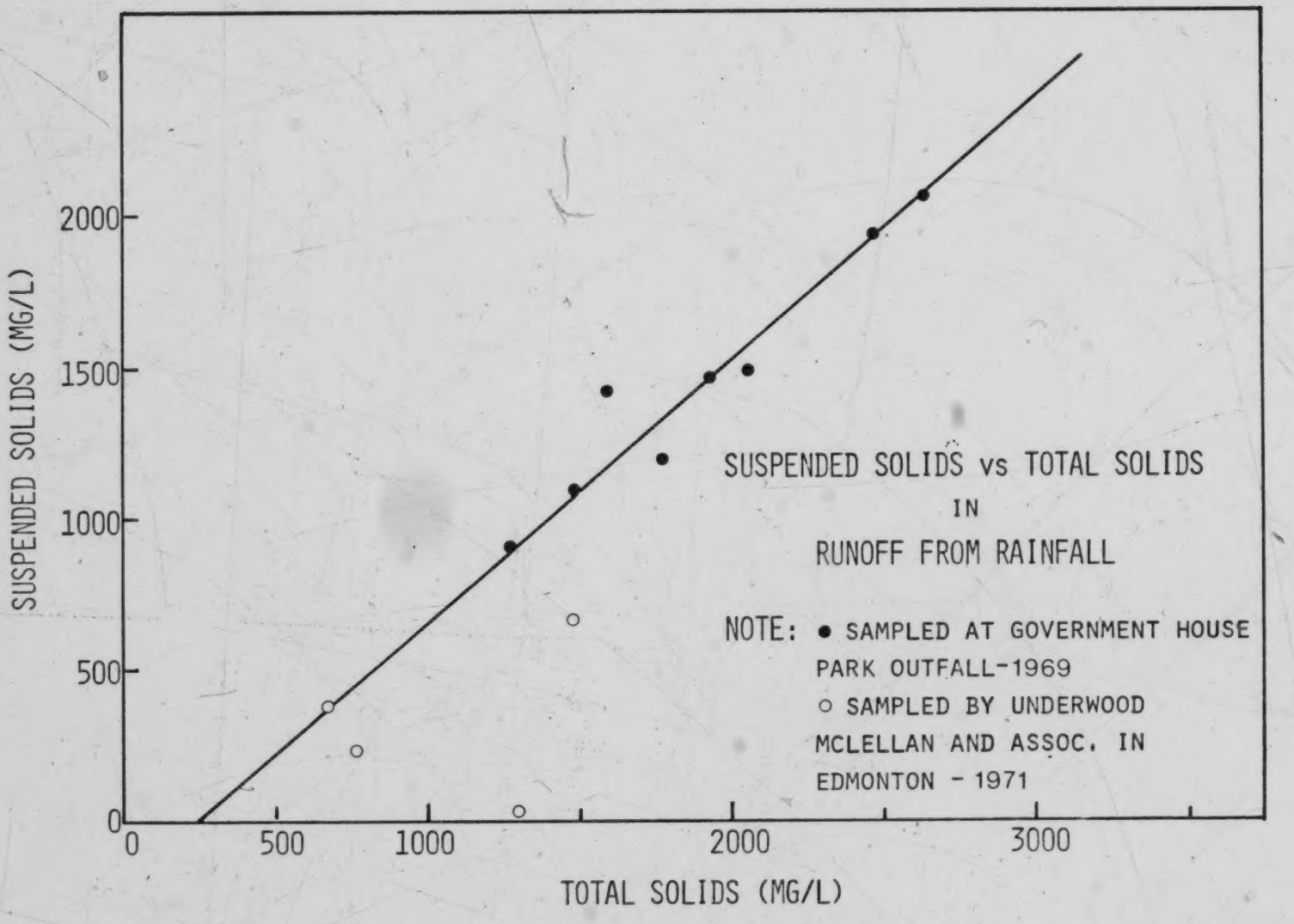

SUSPENDED SOLIDS (MG/L)
2000
1500
1000
500
0
0
500
1000
2000
3000
TOTAL SOLIDS (MG/L)
SUSPENDED SOLIDS vs TOTAL SOLIDS
IN
RUNOFF FROM RAINFALL
NOTE: ● SAMPLED AT GOVERNMENT HOUSE PARK OUTFALL-1969
○ SAMPLED BY UNDERWOOD MCLELLAN AND ASSOC. IN EDMONTON - 1971

FIGURE 10

TABLE C8 was obtained from Underwood McLellan and Associates Limited, who sampled storm water at two outfalls during the summer of 1971. The samples were grab samples and it is not known at what phase of the runoff they were taken. The samples taken at the Groat Bridge (the same outfall as the one referred to as Government House Park outfall in this study), had a considerably higher concentration of dissolved solids in relation to the total solids. This could indicate that the flow was extremely low and the normal groundwater seepage into the storm sewer was dominant.

It is interesting to note the settling rate of the suspended solids. Up to 91 percent removal is indicated within two hours. These results are similar to those obtained by Weibel et al. in Cincinnati (11) and could be indicative of the high percent of inorganic solids.

FIGURE 11 illustrates the rate of BOD-5-20 loading to the river for a typical storm (in this case May 25, 1969 from Government House Park outfall). The maximum rate is approximately 16,400 pounds of BOD-5-20 per day and the average peak hour rate is approximately 14,700 pounds per day. The area of the drainage basin was 3185 acres. If this loading rate was applied to the entire services area of the City, then the loading rate would be 170,000 pounds per day.

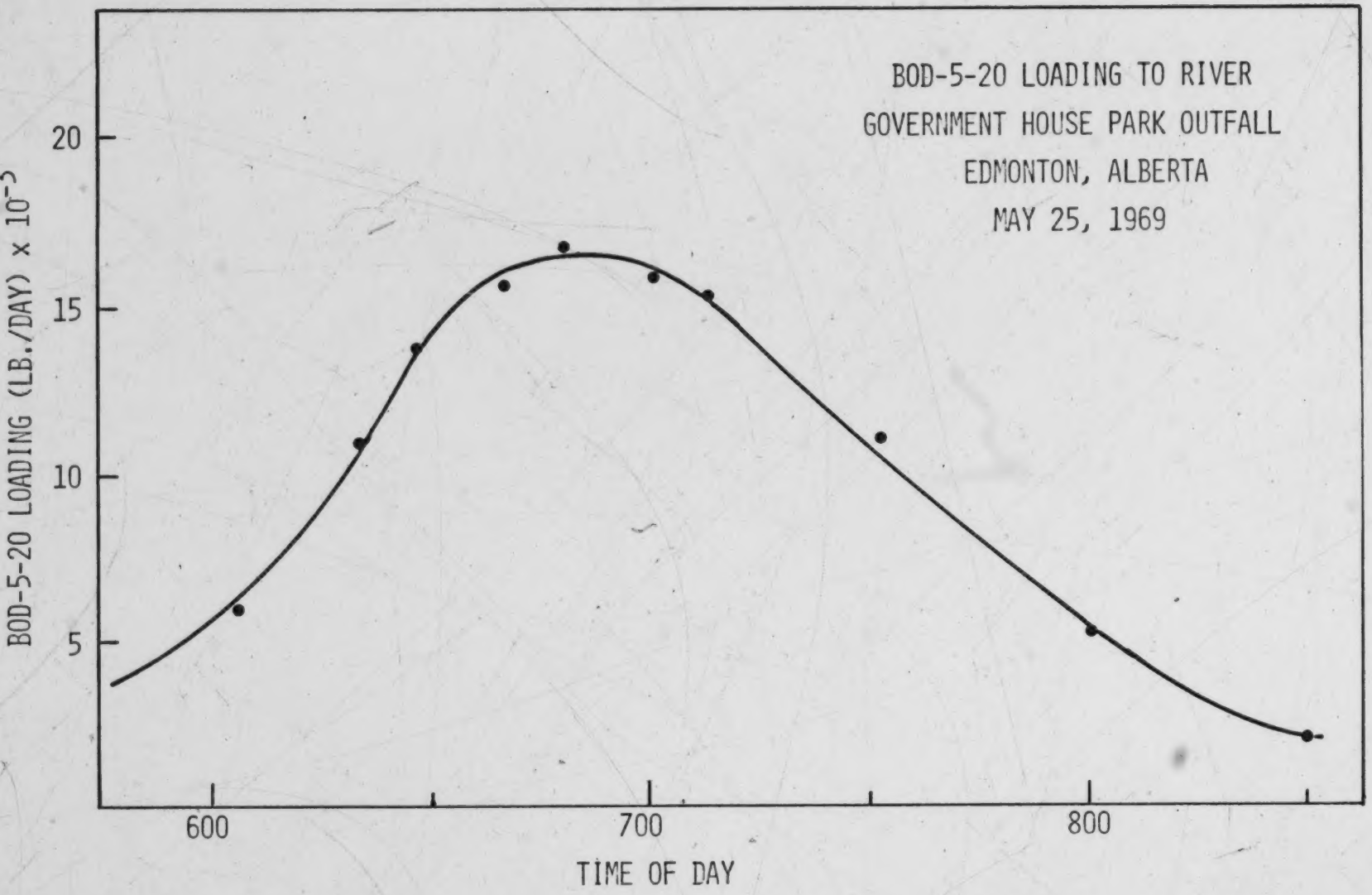

BOD-5-20 LOADING TO RIVER
GOVERNMENT HOUSE PARK OUTFALL
EDMONTON, ALBERTA
MAY 25, 1969
BOD-5-20 LOADING (LB./DAY) x 10^{-3}
20
15
10
5
600
700
800
TIME OF DAY

FIGURE 11

The total pounds of BOD-5-20 per acre in the run-off of each storm was calculated and plotted against the total flow per acre (TABLE VII and FIGURE 12). From the consistency of the results, it would appear that there is a direct relationship between the total loading and the total runoff. For the drainage basin discharging at Government House Park:

Total Pounds of BOD-5-20/acre = 0.284 long Q_t (cf/acre) - 0.263

DeFilippi (15), in a paper presented in the Journal of the Water Pollution Control Federation (October 1971), attempted to obtain a similar relationship plotting total pounds of COD versus total rainfall. The resulting plots shown in FIGURE 13 indicate that a relationship may exist but it is very inconclusive. They hydrographs presented in the paper were taken by this author and extrapolated to the anticipated beginning and the end of the runoff and the total flow was calculated. The results were plotted against the total pounds of BOD-5-20 and total COD as shown in FIGURE 14. These results indicated a relationship similar to the results obtained at Government House Park. From DeFillipe's data, the loading can be defined as:

Total pounds BOD-5-20/acre = 1.18 log (Total Flow cf/acre) -2.56

TABLE VII

BOD-5-20 LOADING AND RUNOFF

AT GOVERNMENT HOUSE PARK

Date 1969	Total Runoff (cf)	Total BOD (#)	Runoff Per Acre (cf)	BOD Per Acre (lbs)
May 25	491,000	1050	154	0.330
May 27	32,100	64	10	0.020
June 6	183,000	740	58	0.232
June 6	522,000	2300	164	0.723
June 23	665,000	393	21	0.123
July 6	539,000	1260	169	0.395

Area of Drainage Basin = 3,185 acres

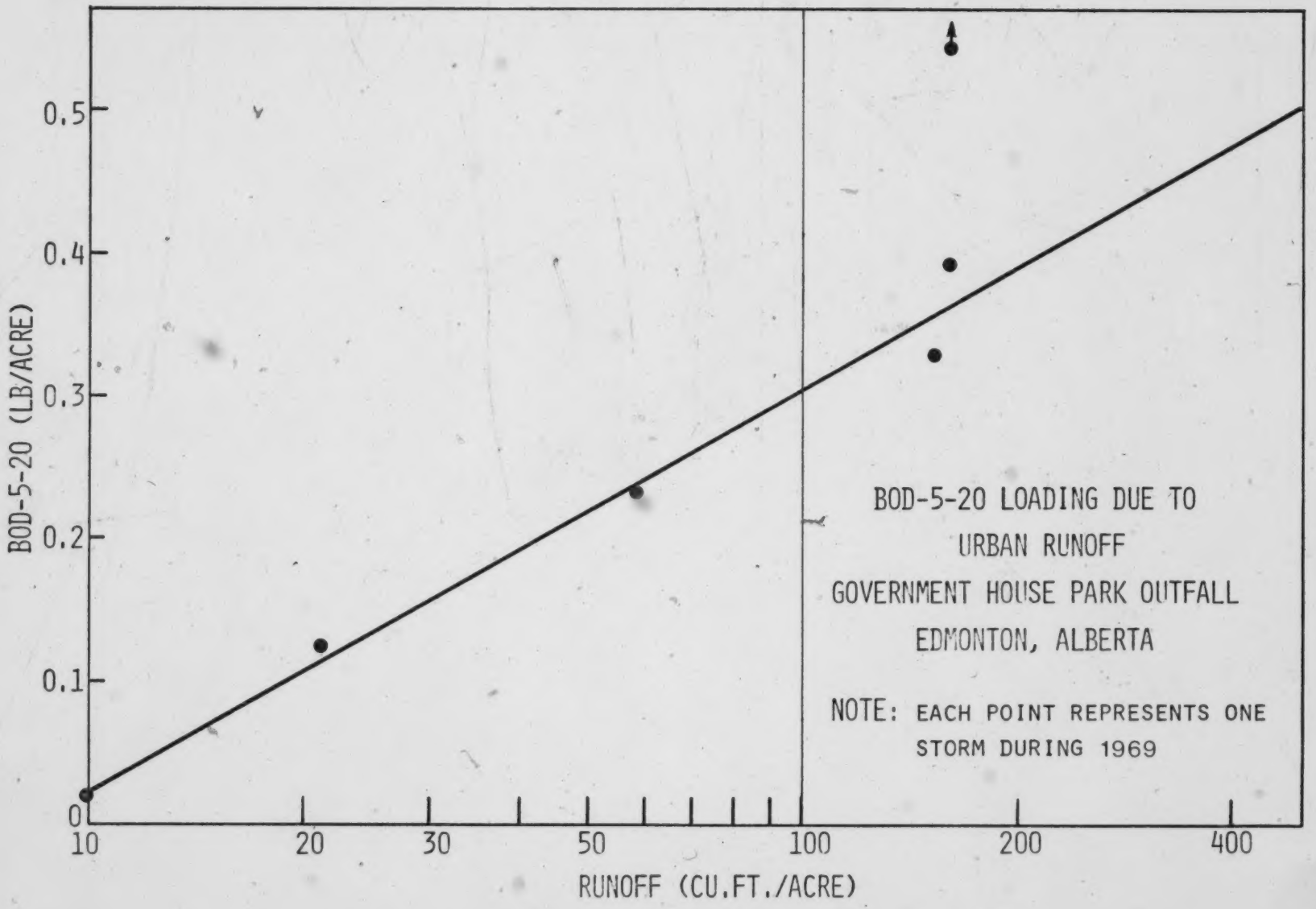

BOD-5-20 (LB/ACRE)
0.5
0.4
0.3
0.2
0.1
0
10
20
30
50
100
200
400
RUNOFF (CU.FT./ACRE)
BOD-5-20 LOADING DUE TO
URBAN RUNOFF
GOVERNMENT HOUSE PARK OUTFALL
EDMONTON, ALBERTA
NOTE: EACH POINT REPRESENTS ONE
STORM DURING 1969

FIGURE 12

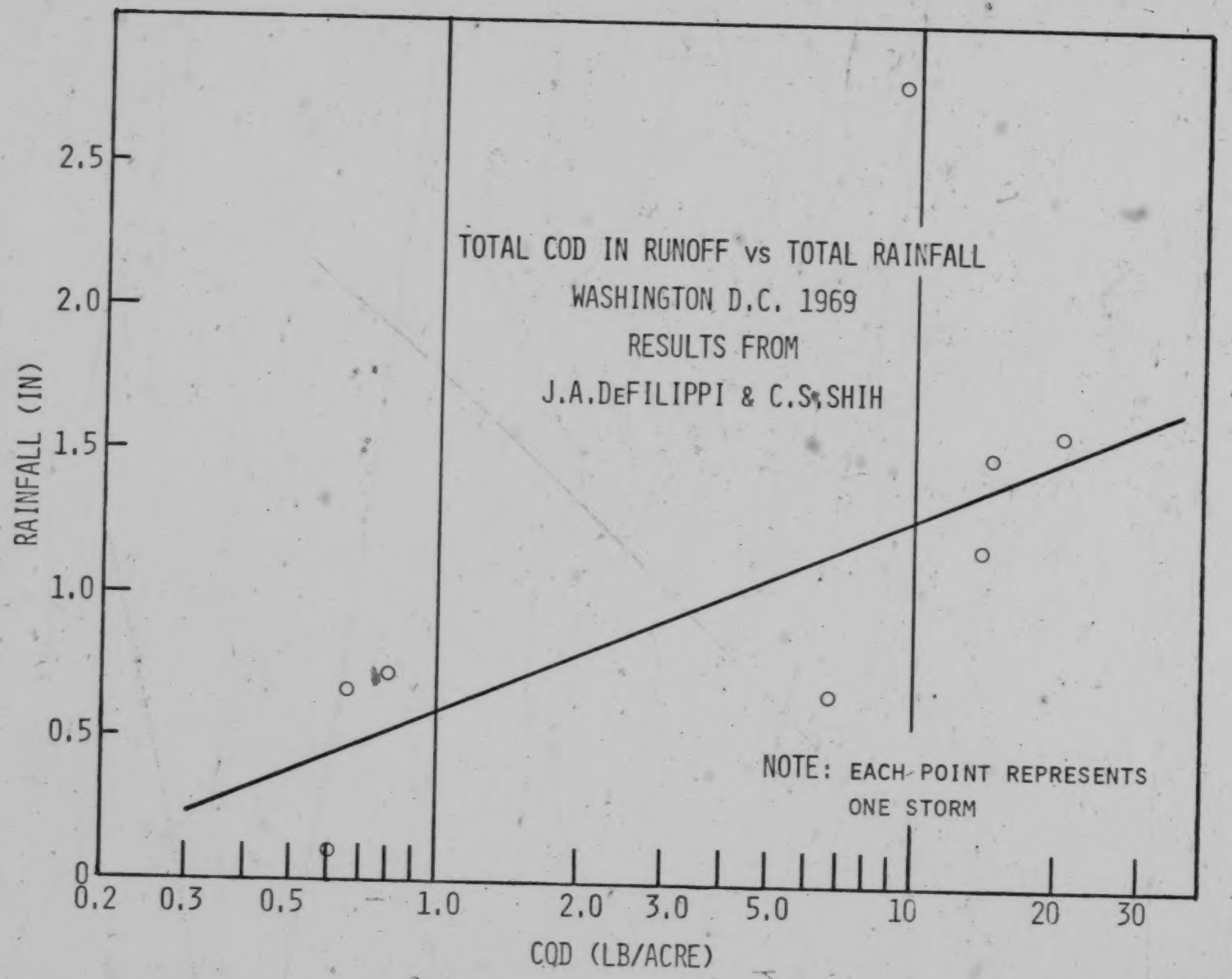

TOTAL COD IN RUNOFF vs TOTAL RAINFALL
WASHINGTON D.C. 1969
RESULTS FROM
J.A.DeFILIPPI & C.S.SHIH
NOTE: EACH POINT REPRESENTS ONE STORM
RAINFALL (IN)
2.5
2.0
1.5
1.0
0.5
0
0.2
0.3
0.5
1.0
2.0
3.0
5.0
10
20
30
COD (LB/ACRE)

FIGURE 13

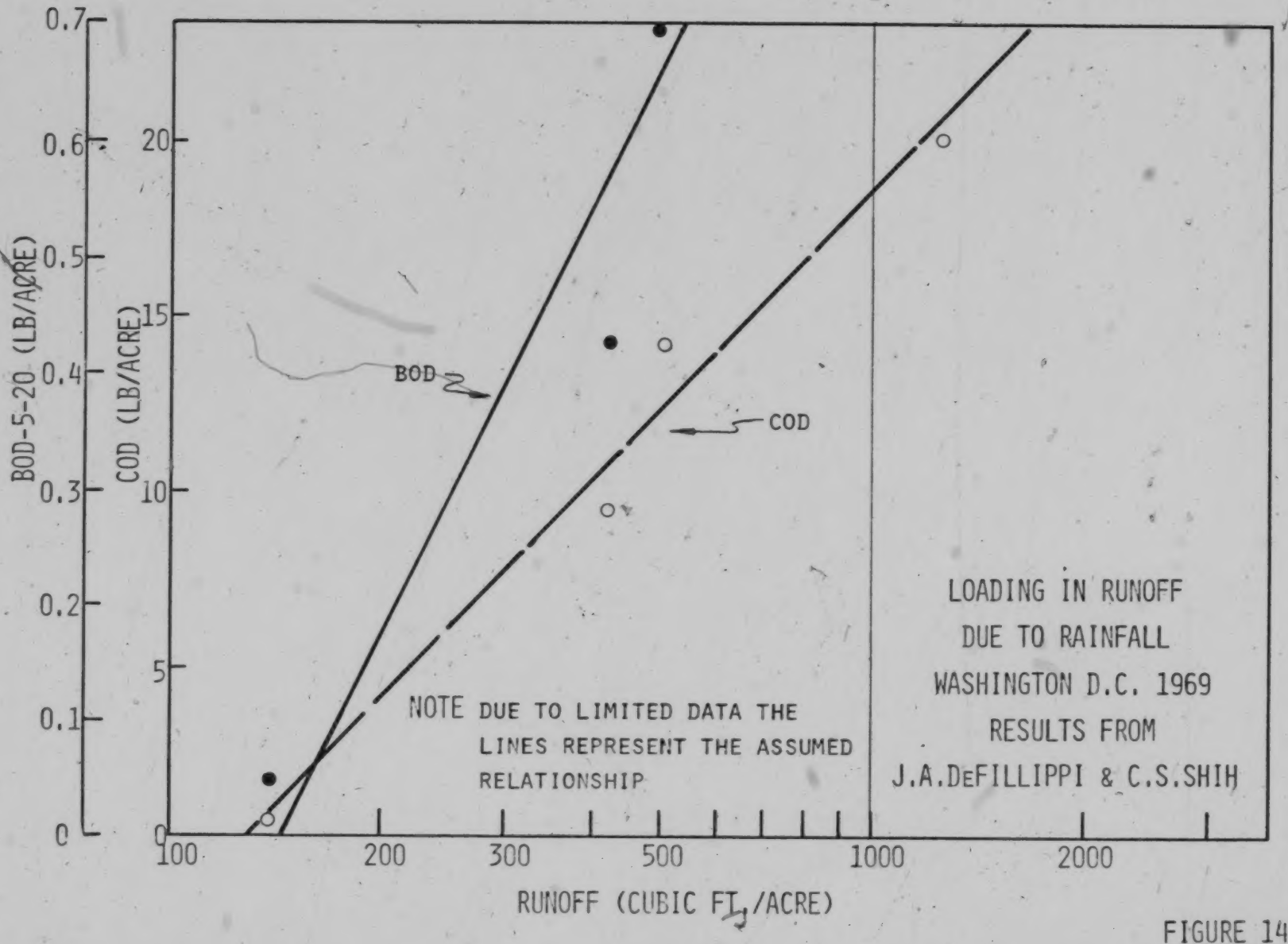

0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
BOD-5-20 (LB/ACRE)
20
15
10
5
0
COD (LB/ACRE)
BOD
COD
NOTE DUE TO LIMITED DATA THE LINES REPRESENT THE ASSUMED RELATIONSHIP
LOADING IN RUNOFF DUE TO RAINFALL WASHINGTON D.C. 1969 RESULTS FROM J.A.DeFILLIPPI & C.S.SHIH
100
200
300
500
1000
2000
RUNOFF (CUBIC FT./ACRE)

FIGURE 14

Total Pounds COD/acre = 21.2 log (Total Flow cf/acre - 44.9

From the above, there appears to be a relationship between total BOD-5-20 and total COD in the runoff and the total runoff from rainfall which could be defined by the equation:

$$L = a \log Q_t + b$$

in which L is total pounds of COD or BOD-5-20 per unit area, Q_t is the total runoff in cubic feet per unit area, and a and b are constants related to the characteristics of the drainage basin. Considerably more work will have be to performed before the constants can be better defined.

The poor results obtained by DeFillippi when plotting loading versus total rainfall could be a result of the difficulty in establishing a relationship between rainfall and runoff. The surface conditions in drainage basins (i.e. saturated or frozen) will greatly influence the runoff from storm to storm. However, the most difficult part in any basin analysis is determining the amount of rain that actually falls on the area being studied. A rain measuring gauge can only determine the rainfall at the point at which it is located. These fingures could be safely interpreted as being representative of the surrounding one or two acres; projection of the results beyond the immediate vicinity may produce large errors.

In DeFilippi's study, the area under consideration for storm runoff was 265 acres. In this area there was one rain gauge. In the Edmonton study, the area under consideration was 3185 acres. There were three rain gauges located near the area, but none in it. For interest sake, the total rainfall versus the total runoff were plotted in FIGURE 5. The rainfall figures used are these from the Edmonton Industrial Airport. This is the gauge nearest the study area and the only one properly installed. The correlation is fair but the deviation of the individual points from the mean indicate that variation could be expected in FIGURE 13 if total rainfall was used instead of total runoff.

To control the rate of runoff some areas such as Winnipeg, Calgary and Minneapolis-St. Paul have created artificial lakes to act as surge ponds for the storm water. Despite the low quality of urban runoff some of these lakes have been quite successful. The lakes are used as aesthetic water bodies and not for active recreation.

In Winnipeg these lakes were initially utilized only in private developments, however, because of the demand, public areas will be provided in the future. In Calgary the lakes are considerably smaller than those in Winnipeg. There is evidence of oil slicks on the water surface, debris floating and accumulated along the shoreline and possible septic conditions.

The discrepency between the two examples above would appear to be due to the considerably lower loading per unit of surface area in Winnipeg.

IV-6 Combined Sewer Overflow

The results of the analysis performed on combined sewer overflow are presented in TABLES D1 to D8 and FIGURES D1 to D8 in Appendix D. The results of each storm overflow are plotted to give a visual presentation of the variation of the concentrations of solids and BOD-5-20 in the sewage by-passed.

The samples taken May 13, 1969 and May 27, 1969 were at the No. 3 sewage treatment plant. The collection system serviced by this plant was 1770 acres with separate sewers and 1450 acres with combined sewers (FIGURE F3). The by-pass was a mixture of sewage from both sources. The BOD-5-20 varied from in excess of 350 mg/1 to 95 mg/1. There appeared to be an initial surge or flushing action after which the loading tended to drop off. No flow measurements were possible at this location, however, it was observed that after the initial flush, the loading tended to vary with estimated flows.

The total solids at this plant varied from 1975 mg/1 to 496 mg/1, and the total volatile solids from 420 mg/1 to 254 mg/1.

The combined sewage samples taken from May 29, 1969 onward were at the main sewage treatment plant. During the

summer of 1969, this plant treated sewage from a collection system that was comprised of 20,380 acres with separate sewers and 13,250 acres with combined sewers. The samples taken represented only plant sewage by-pass, which was a mixture of combined and separate sewage. Since some of the sewers in the combined areas have their own overflows, the sampled sewage by-pass mixture will not be proportional to flows from the combined and separate areas.

Because of the inadequacy of the flow meter at the main sewage treatment plant, by-pass measurements were only recorded on May 29, 1969 and May 30, 1969. During the other storms, the flows were too great to be recorded. The flows recorded in TABLES D3 and D4 are only the amounts by-passed and does not include the increase in flows into the plant. During periods of runoff, the plant was operated at a maximum capacity of 40 mgd (74 cfs).

The BOD-5-20 at the main plant varied during periods of runoff from 407 mg/l to 151 mg/l. The mean of the samples taken at the main plant was 258 mg/l, which is slightly less than the average of 274 mg/l for raw sewage during that summer. In general, the BOD-5-20 was high at the beginning of storms, exhibiting the same flushing action as observed at the No. 3 plant. As the runoff progressed, the loading dropped off.

The total solids varied from 2630 mg/l to 650 mg/l,

while the total volatile solids varied from 692 mg/l to 156 mg/l. In general, the solids were greater than expected in normal sewage but less than observed in runoff from the area serviced by a separate sewer system. There did not appear to be any relationship between the total volatile solids and the BOD5-2-.

Generally, the solids did not exhibit the same flushing action observed for the BOD-5-20, which could indicate that the BOD-5-20 is in a soluble form.

The rate at which BOD-5-20 was by-passed at the main sewage treatment plant on May 29, 1969, was plotted to illustrate the possible loading on the North Saskatchewan River (FIGURE 15). The maximum rate of loading was 113,000 pounds per day and maintained a loading rate in excess of 65,000 pounds per day for approximately an hour. The average loading to the river from both sewage treatment plants during the last half of May (after secondary treatment was stopped) was 65,720 pounds per day. It should be remembered that FIGURE 15 represents only one by-pass of a possible 12 and represents loading for one of the few storms with flows low enough to record.

IV-7 North Saskatchewan River Studies:

On June 23 and 24, 1969, a series of samples were taken from the North Saskatchewan River to determine the impact of the City runoff on the river. The analyses of the

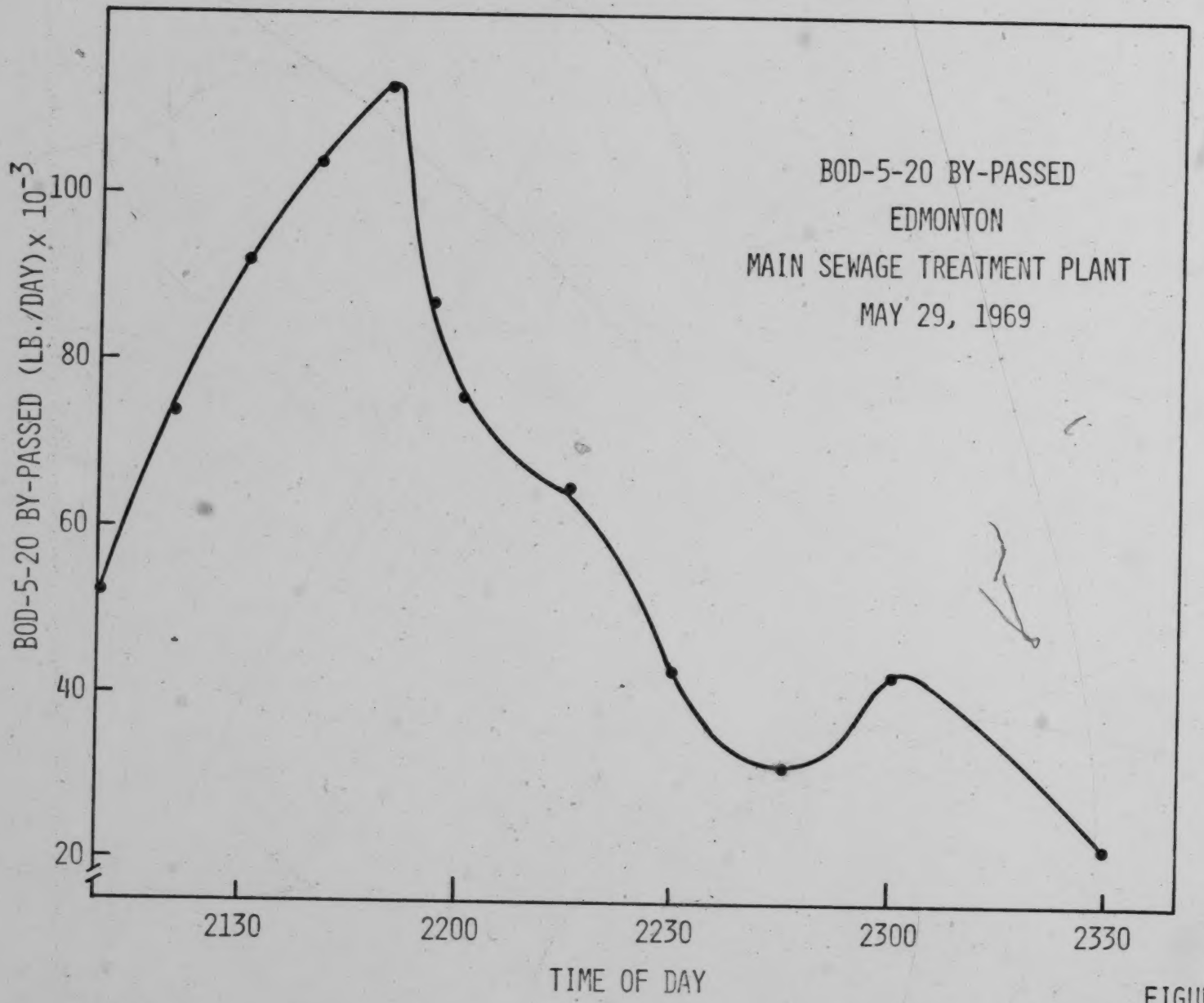

BOD-5-20 BY-PASSED
EDMONTON
MAIN SEWAGE TREATMENT PLANT
MAY 29, 1969
BOD-5-20 BY-PASSED (LB./DAY) x 10^{-3}
100
80
60
40
20
2130
2200
2230
2300
2330
TIME OF DAY

FIGURE 15

samples are recorded in TABLES E1 and E2; the results are also plotted in FIGURES E1 to E3.

On June 23, 1973, the rainfall started at approximately 1100 hours and runoff at the Government House Park outfall started at approximately 1130 hours. The rain stopped at noon and sampling continued until 1240 hours. At this point, with the flows dropping, the author proceeded to Fort Saskatchewan to obtain a sample of the river water prior to it being mixed with the urban runoff. Unfortunately, shortly after 1500 hours, the rain started again and between 1300 and 1400 hours, 0.23 inches were recorded at the Industrial Airport. No samples for this portion of the runoff from a separate system were obtained.

At the main sewage treatment plant, by-passing started shortly after 1100 hours but was light until 1210 hours at which point it started to rise sharply and was off the chart before 1300 hours. Except for a slight drop in flows between 1330 and 1345 hours, the by-pass recorder remained off the chart until 1530 hours. By 1700 hours, the amount of sewage being by-passed had dropped to approximately 15 cfs. Light by-passing continued until about 2200 hours. Between 1230 hours and 1540 hours, 10 samples of the sewage were taken (TABLE D7 and FIGURE D7).

Prior to the storm, the river water at Fort Saskatchewan had a BOD-5-20 value of 1.6 mg/l, a total solids

concentration of 322 mg/l of which 193 mg/l were suspended solids and a dissolved oxygen content of 8.5 mg/l which was approximately 89 percent of saturation.

At approximately 2100 hours, the dissolved oxygen began to drop until it reached 7.3 mg/l at 2240 hours. It then began to rise slowly and was at 8.0 mg/l by 0300 hours on June 24. Simultaneously, the BOD-5-20 rose to 6 mg/l at 2345 hours and dropped to 2.4 mg/l by 0300 hours. The total solids rose to 372 mg/l by 2240 hours and then dropped to 190 by 0150 hours. Both the suspended solids and the total solids rose sharply in the 0300 hours samples.

At the time of the storm, the flow in the river at Edmonton was approximately 13,000 cfs. By 0500 hours on June 24, 1969, it had increased to 14,000 cfs, however, for this discussion, the flow of 13,000 cfs will be used.

Consideration was given as to whether the oxygen sag recorded could be caused by something other than the oxygen demand exerted by runoff from the City of Edmonton. Although no barometer readings were taken during sampling, the possibility of a sudden decline in pressure causing the oxygen sag was ruled out. The maximum variation of the barometer pressure during the month of June 1969 was from 922.5 mb to 945.3 mb or 2.4 percent. Since the river water had a dissolved oxygen content of 89% of saturation, a fluctuation

of pressure of this order would not effect the dissolved oxygen.

The author felt that the North Saskatchewan River did not have diurnal variation in dissolved oxygen due to respiration of aquatic plants. It was assumed that the river is too turbid to permit any significant growth of vegetation and until the fall of 1969, no testing program on the river had revealed a variation that could be attributed to the photosynthetic and respiration process. In October of 1969, the robot monitor at Vinca Ferry was started earlier than usual. For the month of October, the concentration of dissolved oxygen varied diurnally with variations of 80 percent saturation to 129 percent saturation recorded during a single 24 hour period.

It was felt that the oxygen sag recorded on June 23 and 24, 1969, could not be attributed to the respiration of aquatic vegetation, since the oxygen level dropped during day light hours and recovered during darkness.

Another possible source of the dissolved oxygen sag could be discharging of storm runoff and combined sewer by-pass into the river with a low dissolved oxygen content, thus lowering the net dissolved oxygen of the resulting total solution. For example, if 1000 cfs of waste water with zero dissolved oxygen were discharged into the river flowing at 13,000 cfs and having a dissolved oxygen content of 8.5 mg/1.

the resulting solution would have a dissolved oxygen content of 8 mg/l. It is unlikely that this is the case. Although no samples were taken, operators at the main plant claim they cannot control the dissolved oxygen during a rainstorm. The dissolved oxygen in the secondary treatment rises to near saturation and stays there long after it has stopped raining.

From the total rainfall on June 23, 1969 (0.28 inches) it was determined by FIGURE 15 that the total runoff would be 145 cubic feet per acre. Using this number in FIGURE 14 the total BOD-5-20 in the runoff was approximated at 0.35 pounds per acre. Since there were 22,150 acres serviced by separate sewers in the city, the total loading would be 7750 pounds. The combined sewer by-pass at the main plant that day had a mean BOD-5-20 concentration of 37 mg/l.

Using the total flow of 145 cubic feet per acre, the loading from the 14,700 acres serviced by combined sewers would be 29,100 pounds. This gave a predicted total loading on the river of 36,850 pounds of BOD-5-20.

The area under the BOD-5-20 curve in FIGURE E1 was calculated and it was determined there was an increase of 45,800 pounds of BOD-5-20 over the 1.6 mg/l recorded on the afternoon of June 23, 1969. The actual BOD-5-20 loading would be greater than this, since undoubtedly some would have

settled out and from the oxygen sag it is obvious that an appreciable amount has been assimulated.

The oxygen sags witnessed at Fort Saskatchewan were used to determine the maximum oxygen deficit that would be expected as the result of the urban runoff. It was first necessary to determine the coefficient of deoxygenation K_1. The Streeter and Phelps equation for the downstream oxygen profile was used (23).

$$D = \frac{K_1 L_0}{K_2 - K_1} (10^{-K_1 t} - 10^{-K_2 t}) + D_0(10^{-K_2 t}) \qquad (7)$$

where D = dissolved oxygen deficit

L_0 = ultimate or first stage BOD

K_1 = coefficient of deoxygenation (base 10)

K_2 = coefficient of reareation (base 10)

D_0 = initial dissolved oxygen deficit

t = time in days

To convert the five day BOD to the first stage oxygen demand, the formula (23):

$$L_0 = \frac{L}{1 - 10^{-K_1 t}} \qquad (8)$$

was used in which L is the oxygen demand exerted in time t. The first stage BOD was then corrected for temperature using the formula (23).

$$L_{OT} = L_0(1 + 0.02(t-20)) \quad (9)$$

in which L_{OT} is the first stage BOD at the temperature in the water.

The coefficient of reoxygenation was determined using O'Connor's formula (23):

$$K_2 = 0.434 \frac{(D_L\ U)^{1/2}}{H^{3/2}} \quad (10)$$

where D_L = diffusivity of oxygen in water = 0.000081 ft/hr at 20 degrees Centigrade

U = velocity of flow (ft/hr)

H = depth of flow

From examining FIGURE E1, a noticeable increase in loading occurred at approximately 2100 hours. Since heavy by-passing did not occur at the main sewage treatment plant until approximately 1230 hours, the travel time to the Fort Saskatchewan Bridge was 8.5 hours. The mean velocity was therefore 2.26 mph.

From FIGURE 2 the mean depth was assumed to be 3.8 feet at 13,000 cfs.

The coefficients were corrected for temperature using the formula (23):

$$K_t = K\ 20°C\ (1.047^{T-20}) \quad (11)$$

The loading that caused the oxygen sag was assumed

to be the 45,800 pounds recorded in the river and it was assumed that 80% of this loading entered the river during a 3.5 hour period. It was also assumed that the loading was discharged to the river uniformly over 5.5 miles on which there are combined sewer by-passes.

Solving equation (7) for K_1, the deoxygenation coefficient was 0.67/day at 14 degrees Centigrade or 0.88 /day at 20 degrees Centigrade.

The critical time of the maximum oxygen sag was then determined using the formula(23):

$$T_c = \frac{1}{K_2 - K_1} \log \frac{K_2}{K_1} \left[1 - D_0 \frac{(K_2 - K_1)}{K_1 L_0}\right] \qquad (12)$$

The time to the critical oxygen deficit is 0.467 days. At this time, using equation (7) again, the maximum oxygen sag would be 2.25 mg/l indicating that the oxygen sag witnessed at Fort Saskatchewan was very close to the maximum.

For the storm on the evening of June 28, 1969, no surface runoff samples were taken. The river had risen sharply from June 23, 1969 and had a flow of approximately 21,000 cfs at the time of the storm. No samples were obtained of the ambient river water quality at Fort Saskatchewan prior to the effect of the urban runoff. The results of the sampling program were similar to those obtained on June 23 and 24, although the effects were not as noticeable

(FIGURE E3).

In order to determine the critical oxygen deficit the following assumptions were made:

(a) From examination of FIGURE E3, it was estimated that the mean loading that resulted in the dissolved oxygen sag was 3.2 mg/l of BOD-5-20.

(b) The dissolved oxygen curve was extended to the anticipated beginning of the storm and determined to be 8.4 mg/l before being affected by storm runoff. The maximum deficit was 1.55 mg/l with a sag of 0.4 mg/l as the result of storm water.

(c) The mean river depth was 4.8 feet (FIGURE 2).

(d) The travel time between the main sewage treatment plant and the Fort Saskatchewan Bridge was 7 hours.

The deoxygenation coefficient was determined to be 0.50/day at 14 degrees Centigrade or 0.66/day at 20 degrees Centigrade. The critical time was 0.362 days and the critical oxygen deficit was 1.56 mg/l.

The values obtained for the deoxygenation coefficient were extremely high. Normally a value in the range of 0.15 to 0.35/day would be expected.

The rate of oxygen uptake observed in the river is similar to the uptake expected in an activated sludge

plant. Such an effect could take place if an adequate biological mass had accumulated in the river and adequate settling and mixing occurred to bring the loading in contact with this mass. If this were the case, then the only process which would be occurring would be absorption and synthesis. Thus the assimulation of the organic material would occur considerably more quickly than if the proper biological conditions had to be developed to oxidize the wastes.

The storms that occurred on June 23 and June 29, 1969 reduced the oxygen in the river but not to a serious level. To determine how serious this loading would be when the river was at a lower stage an example was worked using the following hypothetical data:

(a) river flow = 5000 cfs

(b) loading to river = 50,000 pounds BOD-5-20 in three hours

(c) temperature = 14 degrees Centigrade

(d) deoxygenation coefficient (K_1) = 0.50/day at 14 degrees Centigrade

(e) initial oxygen deficit = 1.0 mg/l

Using this data and FIGURES 2 and 3, the critical time was determined to be 0.286 per day and the critical oxygen deficit 2.32 mg/l. Because of decreasing depth, the reoxygenation coefficient increases sharply which accounts

for an oxygen deficit less than that obtained from the June 23, 1969 storm (1.05/day to 2.95/day at 14 degrees Centigrade).

From the above it appears that except for extremely severe loading conditions, the runoff through both the combined and separate sewer systems will not result in a serious depletion of oxygen in the North Saskatchewan River when there is no ice cover.

This is not to say that the discharge of combined sewage into the river is unobjectionable. It is still a health hazard and objectionable for aesthetic reasons.

CHAPTER V

SUMMARY AND CONCLUSIONS

V-1 Runoff from Snowmelt

The runoff from snowmelt has a water quality similar to the effluent from a normal secondary sewate treatment plant. Within the limits of this study, it did not however, have any appreciable effect on the water quality of the North Saskatchewan.

Samples taken for this study had chloride contents as high as 400 mg/l which appeared to only produce a change in the chlorides content of the river of 1.5 to 2.5 mg/l. The suspended solid content of the runoff from snowmelt ranges from 22 mg/l to 876 mg/l.

Since urban runoff from snowmelt occurs from the runoff from rural areas, the discharge of snowmelt water into small streams with low winter flows could have toxic effects on fish inhabiting these streams. Concentrations od lead, zinc, copper, ammonia, and oils and greases in runoff from snowmelt were high enough that they might be toxic to some species of fish. The long term effect of the discharges on aquatic life is not known.

V-2 Urban Runoff from Rainfall

The BOD-5-20 in runoff generally decreased as runoff progressed, while the solids content varied with the flow. The strength of the BOD-5-20 samples varied from 18 mg/l to 108 mg/l, averaging 51 mg/l.

No relationship was found between the conductivity provided in reference 15, there would appear to be a relationship between the total amount of runoff and the total BOD-5-20. The relationship can be expressed in the general form:

$$L = a \log Q_t + b \qquad (6)$$

in which L is the total pounds of BOD-5-20 discharged per acre; Q_t is the total runoff per acre and a and b are constants related to the basin characteristics.

For the basin discharging at Government House Park, a = 0.284 and b = -0.263. It is felt that this basin is fairly representative of the greater Edmonton area and that these constants could be used to determine total loading from the City's storm sewer system.

V-3 Combined Sewer Overflow

The BOD-5-20 content of the combined sewage by-pass at the No. 3 and at the main sewage treatment plants varied from 95 mg/l to 407 mg/l. At the main plant the average strength during periods of by-pass was 258 mg/l, which is slightly less than the average strength of raw sewage at the

plant.

The total solids content of combined sewage varied from 496 mg/l to 1975 mg/l and the total volatile solid varied from 254 mg/l to 420 mg/l.

The BOD-5-20 in most cases exhibited a "first flush" while the total solids and total volatile solids did not.

V-4 North Saskatchewan River Studies

The runoff from the City had a noticeable effect on the river downstream at Fort Saskatchewan. The BOD-5-20 and the solids content of the river increased as much as 300 and 29 percent respectively while dissolved oxygen deficits as high as 13 percent were recorded.

The increase of the solids in the river water, although measurable does not seriously effect the river water quality since the river has a high natural solids content. However, organic material settling out in back-waters would produce sludge banks.

Although the urban runoff place a high organic loading on the river and this loading produces a noticeable oxygen deficit, it is felt that the reoxgenation rate is sufficiently high that the dissolved oxygen will not drop low enough to endanger aquatic life.

The Streeter and Phelps formula was applied to the condition found at the Fort Saskatchewan Bridge. For the two sampling programs the deoxygenation coefficients of 0.88 and 0.66/day were obtained. The coefficients are very high and it is theorized that they are high because the river has established biological conditions downstream of the main sewage treatment plant that can quickly assimilate the applied loading.

CHAPTER VI

RECOMMENDATIONS

VI-1 Runoff from Snowmelt

Since urban runoff due to snowmelt contains contaminants in sufficient quantities that it may be toxic to some forms of aquatic life, it is recommended that no storm sewer outfalls be constructed on streams that cannot provide sufficient dilution.

VI-2 Runoff from Rainstorms

It is recommended that further studies be conducted to obtain a better understanding of the constants in formula (6).

Such a study should entail the selection of several small urban drainage basins in which such factors as the surface slope, amount of impermiable surface, land use, permiability of ground, and amount of rainfall can be readily determined.

Automatic flow metering and sampling equipment should be used in such a study.

It is recommended that because of the relatively high level of contaminants in storm runoff, that it now be

discharged into waters used for active recreation where it may stagnate or pond. If such discharge is unavoidable, the users of the area should be made fully aware of the water quality.

VI-3 Combined Sewer Overflow

Because the discharge of large volumes of high strength waste waters during the period of combined sewer overflow conflicts with the expressed public desire to improve water quality in the Province, it is recommended that the feasibility of the removal of the combined sewer overflows by separation or treatment by investigated.

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APPENDIX A

PREVIOUS STUDIES

TABLE A-1

DETROIT - ANALYSES OF STORM RUNOFF (10)

Date of Storm	Number of Samples	Coliform MPN Range	Suspended Solids-Mean (mg/l)	Volatile Solids-Mean (mg/l)
7-13-60	2	150,000 230,000	----	----
7-26-60	2	2,300 43,000	----	----
9-12-60	18	2,300 Min. 25,600 Mean 150,000 Max.	213*	121*
9-19-60	4	9,100 Min. 173,025 Mean 430,000 Max.	102	38

* Based on 15 samples.

TABLE A-2

CINCINNATI - CONSTITUENT CONCENTRATIONS IN URBAN STORMWATER RUNOFF (4)

Constituent	Ranges of Discrete Samples	Storm Average
Turbidity (J.u.)	30 - 1,000	176
Color (C.u.)	10 - 460	87
pH	5.3 - 8.7	7.5
Alkalinity (mg/l.)	10 - 210	59
Total hardness (as $CaCO_3$)(mg/l.)	19 - 364	81
Chloride (mg/l.)	3 - 428	12
SS (mg/l.)	5 - 1,200	227
VSS (mg/l.)	1 - 290	57
COD (mg/l.)	20 - 610	111
BOD (mg/l.)	1 - 173	17
N (mg/l.)(a)	0.3 - 7.5	3.1
Inorganic N (mg/l.)	0.1 - 3.4	1.0
Hydrolyzable PO_4 (mg/l.)	<0.02- 7.3	1.1
Organic chlorine (ug/l.)(b)	0.38- 4.72	1.70

(a) Arithmetic sum of the four forms of nitrogen.
(b) From 11 storms, August 1963 to February 1964.

TABLE A-3

CINCINNATI - CONSTITUENT CONCENTRATIONS IN RAINFALL (5)

Constituent	Storm Ranges	Storm Average
pH	3.9 - 6.1	4.8(b)
SS(mg/1.)	0.5 -58.0	13.0
VSS(mg/1.)	0.5 -12.0	3.8
COD(mg/1.)	4.6 -59.0	16.0
N(mg/1.)(a)	0.5 - 2.8	1.3
Inorganic N(mg/1.)	0.12- 2.3	0.69
Hydrolyzable PO_4(mg/1.)	0.0 - 0.9	0.24
Organic chlorine (ug/1.)	0.08- 0.41	0.28

(a) Arithmetic sum of the four forms of nitrogen.
(b) pH value of 4.8 is median.

TABLE A-4

OHIO - CONCENTRATIONS IN RURAL LAND RUNOFF

FROM A FIELD IN WINTER WHEAT (a) (b) (11)

Parameter	Range	Average
SS (mg/l.)	5-2,074	313
COD (mg/l.)	30-159	79
BOD (mg/l.)	0.5-23	7
N (mg/l.)(N)(c)	2.2-12.7	9
Inorganic N (mg/l.)(N)	0.2-8.2	5
PO_4(total hydrolyzable as PO_4)(mg/l.)	0.25-3.3	1.7
Organic Chlorine (ug/l.)	0.15-0.79	0.43

(a) Contour plowed, adequate fertilization, and pest control, corn, wheat, 1st year meadow, and 2nd year meadow, annual rotation.
(b) All values represent composite samples, one per storm-runoff event.
(c) Arithmetic sum of the four forms of nitrogen.

TABLE A - 5

DETROIT AND ANN ARBOR - SUMMARY OF BACTERIOLOGICAL QUALITY OF OVERFLOWS (7)

Month	Overflows Successfully Monitored		Analysis	Median Densities Of Geometric Means		Ratio Detroit/ Ann Arbor
	Ann Arbor	Detroit		Ann Arbor (a)	Detroit (b)	
March	0	4	Tot. Col.	---------	2,300,000	----
April	3	11	Tot. Col.	340,000	2,400,000	7:1
			Fec. Col.	10,000	890,000	89:1
			Fec. Strep.	20,000	---------	---
May	2	7	Tot. Col	510,000	4,400,000	9:1
			Fec. Col.	51,000	1,500,000	29:1
			Fec. Strep.	200,000	320,000	2:1
June	5	9	Tot. Col.	4,000,000	12,000,000	3:1
			Fec. Col.	78,000	2,700,000	35:1
			Fec. Strep.	120,000	740,000	6:1
July	5	11	Tot. Col.	4,000,000	37,000,000	9:1
			Fec. Col.	120,000	7,600,000	63:1
			Fec. Strep.	390,000	350,000	1:1
August	7	10	Tot. Col.	1,700,000	26,000,000	15:1
			Fec. Col.	350,000	4,400,000	13:1
			Fec. Strep.	310,000	530,000	2:1
September	0	11	Tot. Col.	---------	22,000,000	----
			Fec. Col.	---------	5,400,000	----
			Fec. Strep.	---------	600,000	----
October	0	2	Tot. Col.	---------	43,000,000	----
			Fec. Col.	---------	3,100,000	----

(a) Separate storm outfalls

(b) Combined sewer system

TABLE A-6

DETROIT AND ANN ARBOR - ANALYSES OF COMBINED AND SEPARATE STORM SEWER DISCHARGES (8)

Analyses	Ann Arbor Separate		Detroit Combined	
	Maximum Value Observed	Annual Mean*	Maximum Value Observed	Annual Mean*
Phenols (ug/1.)	70	16	8,000	312
BOD (mg/1.)	62	28	685	153
NH_3-N (mg/1.)	2.0	1.0	134	12.6
Organic N (mg/1.)	4.0	1.0	38.4	3.7
SS (mg/1.)	11,900	2,080	804	274
VSS (mg/1.)	570	218	452	117
Sett.Solids (mg/1.)	11,100	1,590	656	238
Vol.Sett.Solids (mg/1.)	475	140	376	97
Soluble PO_4 (mg/1.)	3.4	0.8	21.2	7.7
Total PO_4 (mg/1.)	16.4	5.0	43.2	14.6
NO_3-N (mg/1.)	3.6	1.5	2.8	0.5

* Values for extreme slugs of a particular parameter were included in the computations for the annual mean.

TABLE A-7

CLEVELAND - ANALYSES OF COMBINED SEWAGE (14)

Location of Outfall	COD (mg/1)	BOD (mg/1)	SS (mg/1)	Phos. P (mg/1)	Kjel. Nitrogen N (mg/1)	Nitrate as N* N (mg/1)	Total N (mg/1)
Combined sewer outfall:							
E.79	384	61.5	211	2.24	8.8	0.1	8.9
E.88	260	52.4	114	2.16	10.6	0.1	10.7
Easterly overflow	310	53.1	126	2.53	13.1	0.1	13.2
E.156	140	31.2	85	1.6	6.2	0.1	6.3
Green Cr.	93	11.7	130	0.43	2.3	0.2	2.5
Neff Rd.	64	7.4	33	0.16	0.8	0.1	0.9

TABLE A-8

SUMMARY OF REPORTED CHARACTERISTICS OF STORM WATER BACTERIOLOGICAL ANALYSES

MPN/100 ml.

Location	Coliform	Fecal Coliform	Fecal Strep.
Detroit and Ann Arbour (a,b)	34,000 to 4,000,000	10,000 to 350,000	20,000 to 39,000
Detroit and Ann Arbour (b,c)	26,500 to 17,500,000	9,800 to 1,115,000	18,450 to 730,000
Oakland, Cal.	4 to 70,000 11,800		
Detroit	25,000 to 230,000		
	2,300 to 430,000		
Toronto	4,300 to 180,000		
Welland	16,800		
Cincinnati (g) (i)	2,900 460,000	500 76,000	4,900 110,000
Ohio, Rural Fields (g)	80 to 1,800 36,000 to 180,000	2 to 22 80 to 56,000	24 to 1,200 4,800 to 150,000
Stockholm	40 to 200,000		
Pretoria (h)	230,000 240,000		
Seattle (Gutter Runoff)	16,000		

(a) Range of Median Densities of Geometric Means
(b) Range of Median Values
(c) References 1 & 2 each used data from the same study
(d) Range; Average
(e) Gutter Runoff; Business District 1950; 1960
(f) Range of Two Overflow Points
(g) Densities Exceeded in 90% & 10% of samples
(h) Residential, Park Area; Business & Flat Areas
(i) A sample of Stormwater Containing 3.8×10^6/100 ml to 0.45×10^6/100 ml Fecal Coliforms and 3.7×10^6/100 ml. yielded Salmonella Thompson.

TABLE A-9

SUMMARY OF REPORTED CHARACTERISTICS OF STORM RUNOFF SOLIDS ANALYSES

Location	Total Solids mg/l	Volatile Solids mg/l	Susp.Solids mg/l	Vol.S.S. mg/l	Sett.Solids mg/l	Vol.Sett.Sc mg/l
Detroit & Ann Arbor			1,280			
Detroit & Ann Arbor (a)			11,900	570;218	11,100;1,590	475;140
Oakland, Cal. (b)	1,401	168 to 168; 168	16 to 4,400; 613			
Detroit	310 to 726	136 to 370 38 to 121	102 to 213			
Toronto			150 to 430			
Welland	332		58			
Washington - Great Basin			26 to 36,250; 2,100			
Los Angeles			1,534 to 7,330			
Cincinnati (b)			5 to 1,200 227	1 to 290 57		
Ohio - Rural Fields (b)			5 to 2,074 313			
Stockholm	30 to 8,000					
Moscow			1,000 to 3,500			
Leningrad			14,541			

TABLE A-9 (Continued)

Location	Total Solids mg/l	Volatile Solids mg/l	Susp.Solids mg/l	Vol.S.S. mg/l	Sett.Solids mg/l	Vol.Sett.Sol mg/l
Oxney, Eng.			1,791 Max.			
Sheffield, Eng.			263 to 1,335			
Meywood, Eng.			180 to 2,380			

(a) Maximum: Annual Mean
(b) Range: Runoff

TABLE A-10

SUMMARY OF REPORTED CHARACTERISTICS OF

STORM RUNOFF BIOCHEMICAL OXYGEN DEMAND ANALYSIS

Location	BOD-5-20 (mg/1)
Detroit and Ann Arbor (a)	62;28
Oakland, Cal. (b)	3 to 700;87
Detroit	96 to 234 (c)
Toronto	12 to 19
Washington (Catch Basin (b)	6 to 625;126
Cincinnati (b)	1 to 173;17
Ohio, Rural Field (b)	0.5 to 23;7
Stockholm	17-80
Moscow	18-285
Leningrad	36
Oxney, England	20 to 100
Pretoria	30;34 (d)
Seattle, Gutter Run-off	10

(a) Maximum: Annual Mean
(b) Range: Average
(c) Gutter Runoff - Business District - 1950
(d) Residential Park Area: Business & Flat Areas

TABLE A-11

SUMMARY OF REPORTED CHARACTERISTICS OF STORM RUNOFF NITROGEN AND PHOSPHATES ANALYSES

Location	Total PO_4 (mg/l)	Nitrogen (mg/l)			
		NH_3	NO_3	Org.	Total
Detroit & Ann Arbor (a)	2.9	0.48	-------	0.36	--------
Detroit & Ann Arbor (b)	16.4:5.0	2.0:1.0	3.6:1.5	4.0:1.0	--------
Cincinnati (c)	0.20 to 7.3 1.1	-------	--------	0.26 to 4.1:2.1	0.3 to 7.5 3.1
Ohio Rural Fields (c)	0.25 to 3.3 1.7	-------	--------	2 to 4.5 4.0	2.2 to 12.7 9.0

(a) Statistical Mean
(b) Maximum: Annual Mean
(c) Range: Average

TABLE A-12

SUMMARY OF REPORTED CHARACTERISTICS OF

COMBINED SEWAGE BACTERIOLOGICAL ANALYSES

Location	MPN/100 ml. Coliform	Fecal Coliform	Fecal Strep.
Detroit and Ann Arbor (a)(c)	2,300,000 to 43,000,000	890,000 to 7,600,000	320,000 to 740,000
Detroit and Ann Arbor (b)(c)	495,000 to 90,000,000	200,000 to 17,000,000	295,000 to 1,574,000
Oakland, Cal. (d)	2,300 to 2,400,000; 293,000		
Oakland County, Michigan	500,000		
Detroit	4,300,000		
Toronto	23,000 to 3,500,000		
Welland	210,000		

(a) Range of Median Densities of Geometric Means
(b) Range of Median Values
(c) References 1 & 2 each used data from the same study
(d) Range: Average

TABLE A-13

SUMMARY OF REPORTED CHARACTERISTICS OF COMBINED SEWAGE SOLIDS ANALYSES

Location	Combined Sewage					
	Total Solids mg/l	Volatile Solids mg/l	Susp. Solids mg/l	Vols. S.S. mg/l	Sett Solids mg/l	Vol. Sett Sol.
Detroit and Ann Arbor			150			
Detroit and Ann Arbor (a)			804; 274	452; 117	656; 238	376; 97
Oakland, California (b)	132 to 1327; 400	83 to 291; 144	60 to 1120; 203			
Detroit			250	100		
Toronto			17 to 939			
Welland	850 to 960		168 to 426			
Buffalo	754, 785	362, 79	436, 544 208 to 4970	196, 350	(ml/l) 1/2 hr. -3 to 4.5 1 hr. -3.5 to 4.5	
British Cities (c)			147 to 685			
New York (d)			[illegible] max.	120 max.	210 max.	
Northampton (e)			[illegible] to 4,[illegible]00			
Bradford (e)			260 to 430			
Brighouse (e)			400 to 1,000			
Baltimore (f)	128 to 2,509	53 to 1,383				
Oakland Co'y Michigan			198	50		

(a) Annual Maximum and Mean
(b) Range, Average
(c) Range of average values from eighteen cities
(d) Variation in one storm
(e) Depending on time in storm and period since last storm
(f) Variation in two storms

TABLE A-14

SUMMARY OF REPORTED CHARACTERISTICS OF COMBINED SEWAGE

BIOCHEMICAL OXYGEN DEMAND ANALYSES

Location	BOD-5-20 mg/l
Detroit and Ann Arbor (a)	685;153
Oakland, Cal. (b)	13 to 153;59
Detroit	50
Toronto	0 to 260
Welland	220 to 614
Northampton	70 to 600
Brighouse	20 to 180
Bradford	50 to 60
Oakland County, Michigan	52
Buffalo	100 to 121

(a) Maximum: Annual Mean
(b) Range: Average

TABLE A-15

SUMMARY OF REPORTED CHARACTERISTICS OF

COMBINED SEWAGE NITROGEN AND PHOSPHATE ANALYSIS

	Combined Sewage (mg/l)				
	PO_4		Nitrogen		
Location	Total	Sol	NH_3	NO_3	Org.
Detroit and Ann Arbor (a)	9.0		3.25		0.37
Detroit and Ann Arbor (b)	43.2: 14.6	21.2: 7.7	13.4: 12.6	2.8: 0.5	38.4: 3.7
Northampton			2 to 23		
Brighouse			2 to 5		
Bradford			3 to 8		

(a) Statistical Mean
(b) Maximum: Annual Mean

APPENDIX B

ANALYSES OF RUNOFF FROM SNOWMELT

TABLE B-1

CHLORIDE & SUSPENDED SOLIDS ANALYSES OF RUNOFF FROM SNOWMELT

GOVERNMENT HOUSE PARK - 1969

		Chloride mg/l	Suspended Solids mg/l
March 4	3:30 pm	27	
	7:00 pm	41	
	11:45 pm	24	22
March 5	9:00 am	13	
	1:00 pm	109	25
	6:00 pm	377	
March 6	12:15 am	136	109
	9:00 am	29	160
	12:15 pm	35	288
	5:30 pm	357	240
	11:30 pm	127	
March 7	5:30 pm	23	
March 8	9:00 am	11	
	5:00 pm	43	
March 9	6:00 pm	400	
March 11	12:15 pm	185	96
	6:00 pm	400	
March 12	1:00 pm	245	98
March 13	7:00 pm	285	
March 14	2:00 pm	280	376
March 16	12:15 pm	75	138
	4:00 pm	135	
	11:30 pm	105	
March 17	1:00 pm	370	390
	6:30 pm	330	
March 18	9:30 am	285	
	7:00 pm	215	314
	11:55 pm	185	
March 19	1:30 pm	340	
	7:00 pm	130	
March 20	12:05 am	120	490
	12:20 pm	235	784
	7:00 pm	140	896
March 21	12:10 am	80	
	9:00 am	90	
	2:00 pm	100	
	5:00 pm	65	
March 22	12:30 pm	70	460
	7:00 pm	50	
March 24	7:00 pm	34	768
March 25	12:30 pm	44	
	7:00 pm	65	788
March 28	5:30 pm	68	352
March 30	5:30 pm	465	784

TABLE B-2

ANALYSES OF RUNOFF FROM SNOWMELT (EDMONTON)

March 15, 1972

	Quesnell Bridge (south side)	Near Whitemud Creek	Emily Murphy Park	Near Groat Bridge (N. side)
pH	7.6	7.0	7.1	7.0
Iron, Total mg/l	0.7	1.0	12.0	0.8
Nitrate + Nitrite mg/l	0.8	0.3	0.4	0.2
Potassium mg/l	40	3.8	5.3	4.0
Alkalinity, Total mg/l	125	100	80	95
Sulfate mg/l	50	35	25	25
Sodium mg/l	400	113	200	63
Threshold Odor Number	20	500	100	500
Oil and Grease mg/l	1.3	32.7	12.6	25.2
Phenols mg/l	0.018	0.050	0.048	0.020
Cadium mg/l	0.005	0.003	0.003	0.003
Chromium, Total mg/l	0.019	0.022	0.030	0.040
Cobalt mg/l	0.026	0.020	0.027	0.019
Copper mg/l	0.020	0.027	0.065	0.147
Lead mg/l	0.446	0.949	1.339	0.781
Manganese mg/l	0.557	1.076	1.376	0.903
Mercury mg/l	0.0005	0.0005	0.0011	0.0009
Nickel mg/l	0.057	0.053	0.067	0.017
Selenium mg/l	0.02	0.01	0.01	0.01
Zinc mg/l	0.353	0.496	0.642	0.438

TABLE B-3

ANALYSES OF RUNOFF FROM SNOWMELT (EDMONTON)

March 20, 1972

	Quesnell Bridge (south side)	Quesnell Bridge (north side)	Near Whitemud Creek	Groat Bridge (north side)	Emily Murphy Park
pH	7.7	7.3	7.1	7.0	7.3
Alkalinity ($CaCO_3$) mg/l	105	60	70	85	45
Threshold Odor Number	10	10	10	100	20
Oils and Grease mg/l	0.1	4.2	4.3	8.6	0.5
Phenols ppb	3	13	2	5	2
Chlorides mg/l	28	38	40	42	30
Nitrate nitrogen mg/l	0.6	0.7	0.6	0.5	0.4
Sulfates mg/l	60	30	35	45	15

TABLE B-4

ANALYSES OF RUNOFF FROM SNOWMELT (EDMONTON)

March 23, 1972

	Aspen Drive West	East of Dawson Bridge	Capilano Bridge (south east)
pH	8.5	7.1	7.1
Alkalinity ($CaCO_3$) mg/l	105	195	140
Threshold Odor Number	2	200	100
Oils and Grease mg/l	4.3	15.8	11.7
Phenols ppb	15	1	30
Chlorides mg/l	39	70	56
Nitrate + Nitrite mg/l	0.8	0.1	0.1
Sulfates mg/l	45	--------	--------
Cadmium mg/l	0.001	0.003	0.005
Chromium, Total mg/l	0.022	0.176	0.045
Cobalt mg/l	0.010	0.021	0.020
Copper mg/l	0.050	0.119	0.071
Lead mg/l	0.013	1.291	0.958
Manganese mg/l	0.453	1.192	0.990
Mercury mg/l	0.0005	0.0005	0.0005
Nickel mg/l	0.036	0.085	0.090
Selenium mg/l	0.02	0.01	0.01
Zinc mg/l	0.159	0.941	1.011

TABLE B-5

ANALYSES OF RUNOFF FROM SNOWMELT (EDMONTON 1969)

	GROAT ROAD			EMILY MURPHY PARK	
	April 2	April 3	May 12	April 2	April 3
Biochemical Oxygen Demand mg/1	25	24	------	21	23
Chemical Oxygen Demand mg/1	141	246	------	191	265
pH	7.8	7.9	7.7	8.2	8.3
Alkalinity ($CaCO_3$) mg/1	107	83	531	68	97
Threshold Odor Type	earthy	earthy	------	earthy	earthy
Threshold Odor Number	200	200	------	1000	100
Total Residue mg/1	738	762	1448	920	1224
Ignition Loss mg/1	192	184	400	212	230
Non-filtrable Residue mg/1	335	585	------	548	908
Ignition Loss mg/1	48	128	------	98	95
Phenols ug/1	10	14	------	8	11
Chlorides mg/1	40	40	30	80	50
Total Phosphorous mg/1	4.5	8.8	0.1	5.0	10.0
Ammonia Nitrogen (NH_3-N) mg/1	2.9	2.5	1.4	3.2	2.4
Nitrate Nitrogen (NO_3-N) mg/1	0.7	0.7	0.4	0.9	0.7
Sulfates mg/1	140	92	725	60	54
Fluorides mg/1	------	------	0.13		
Total Coliforms per 100 mls	------	9.5	------	------	4.5
E Coli per 100 mls	------	1.8	------	------	negative
Standard Plate Count per ml	------	400,000	------	------	600,000
Oils and Grease mg/1	4.4	10.6	------	2.7	8.1

TABLE B 6

ANALYSIS OF RUNOFF FROM SNOWDRIFT - LAURIER PARK (EDMONTON)

Date	22/3/73	8/3/73
pH	6.9	7.4
Specific Conductance umho/cm	2300	1380
Hardness, Total mg/l	100	145
Alkalinity, Total mg/l	72	80
Sulfate mg/l	45	260
Chloride mg/l	698	300
Nitrate + Nitrite mg/l	0.9	0.7
Iron, Total mg/l	2.8	11.5
Calcium mg/l	31	45
Magnesium mg/l	6	8
Sodium mg/l	470	235
Potassium mg/l	6.5	5.5
Phosphate mg/l	1.9	2.8
Ammonia - N mg/l	1.4	1.5
Biochemical Oxygen Demand mg/l	26	200
Chemical Oxygen Demand mg/l	190	330
Oil and Grease mg/l	5.0	1.4
Phenols mg/l	0.014	0.008
Threshold Odor Number	8	8
Turbidity	15	15
Total Solids mg/l	1540	1420
Non-filtrable Residue mg/l	170	650
Cobalt mg/l	0.029	0.037
Copper mg/l	0.009	0.037
Manganese mg/l	0.060	0.076
Nickel mg/l	0.170	0.200
Cadmium mg/l	<0.001	0.008
Chromium mg/l	0.022	0.052
Lead mg/l	0.455	0.062
Mercury mg/l	<0.0005	<0.0005
Nitrite mg/l	0.2	<0.1
Hydrocarbons mg/l	<0.001	<0.001
Benzo-a-Pyrene mg/l	<0.001	<0.001
Color - Filter #1	98.0	98.5
Filter #2	97.0	96.5
Filter #3	93.0	92.0

<- Less than

TABLE B-7

ANALYSES OF RUNOFF FROM SNOWMELT

NORTH END OF QUESNELL BRIDGE (EDMONTON)

Date	29/3/73
pH	7.2
Specific Conductance umho/cm	850
Hardness, Total mg/l	264
Alkalinity, Total mg/l	107
Sulfate mg/l	110
Chloride mg/l	79
Nitrate + Nitrite mg/l	6.0
Iron, Total mg/l	0.1
Calcium mg/l	82
Magnesium mg/l	14
Sodium mg/l	45
Potassium mg/l	4.4
Phosphate mg/l	2.5
Ammonia - N mg/l	1.7
Biochemical Oxygen Demand mg/l	11
Chemical Oxygen Demand mg/l	98
Oil and Grease mg/l	4
Phenols mg/l	0.04
Threshold Odor Number	8
Turbidity	>15
Total Solids mg/l	1280
Non-filtrable Residue mg/l	760
Cobalt mg/l	0.012
Copper mg/l	0.013
Manganese mg/l	0.075
Nickel mg/l	0.095
Cadmium mg/l	<0.001
Chromium mg/l	0.038
Lead mg/l	0.012
Mercury mg/l	<0.0005
Nitrite mg/l	<0.1
Color - Filter #1	93.5
Filter #2	90.0
Filter #3	69.5

> - Greater than
< - Less than

TABLE B-8

ANALYSES OF RUNOFF FROM SNOWMELT

EMILY MURPHY PARK (EDMONTON)

Date	22/2/73
pH	7.0
Specific Conductance umho/cm	2150
Hardness, Total mg/l	231
Alkalinity, Total mg/l	142
Sulfate mg/l	82
Chloride mg/l	583
Nitrate + Nitrite mg/l	0.9
Iron, Total mg/l	4.4
Calcium mg/l	75
Magnesium mg/l	11
Sodium mg/l	360
Potassium mg/l	8.8
Phosphate mg/l	2.4
Ammonia - N mg/l	0.58
Biochemical Oxygen Demand mg/l	25
Chemical Oxygen Demand mg/l	260
Oil and Grease mg/l	9.0
Phenols mg/l	0.03
Threshold Odor Number	16
Turbidity	15
Total Solids mg/l	2400
Non-Filtrable Residue mg/l	710
Cobalt mg/l	0.026
Copper mg/l	0.018
Manganese mg/l	1.160
Nickel mg/l	0.08
Cadmium mg/l	0.001
Chromium mg/l	0.026
Lead mg/l	0.4
Mercury mg/l	0.0005
Nitrite mg/l	0.2
Color - Filter #1	96.0
Filter #2	95.0
Filter #3	90.0

TABLE B-9

ANALYSIS OF RUNOFF FROM SNOWMELT

NEAR DAWSON BRIDGE (EDMONTON)

Date	14/3/73	16/3/73	20/3/73	22/3/73	29/3/73
pH	7.6	7.2	7.1	7.6	7.1
Specific Conductance umho/cm	1800	640	360	750	430
Hardness, Total mg/l	640	122	102	288	166
Alkalinity, Total mg/l	207	86	77	157	75
Sulfate, mg/l	450	50	33	180	62
Chloride mg/l	225	180	40	34	35
Nitrate & Nitrite mg/l	0.5	2.3	2.0	11.0	1.6
Iron, Total mg/l	3.8	0.3	1.3	0.3	0.4
Calcuim mg/l	94	43	28	94	46
Magnesuim mg/l	99	3	7	13	12
Sodium mg/l	140	115	24	29	18
Potassium mg/l	17.0	14.0	6.0	14.0	1.2
Phosphate mg/l	10.4	1.1	2.6	4.4	2.4
Ammonia - N mg/l	18	3.3	4.0	6.4	1.2
Biochemical Oxygen Demand mg/l	52	45	12	20	9
Chemical Oxygen Demand mg/l	200	310	80	70	10
Oil and Grease mg/l	6.0	9.0	2.3	2.0	5.8
Phenols mg/l	0.015	0.007	0.001	0.006	0.008
Threshold Odor Number	32	8	8	4	4
Turbicity	>15	>15	>15	>15	>15
Total Solids mg/l	370	1626	666	560	348
Non-Filtrable Residue m/gl	70	1210	332	36	55
Cobalt mg/l	0.035	0.022	0.001	0.001	0.003
Copper mg/l	0.022	0.036	0.017	0.006	0.011
Manganese mg/l	0.860	1.400	0.024	0.026	0.043
Nickel mg/l	0.320	0.220	0.270	0.028	0.008
Cadmium mg/l	0.002	0.003	0.005	0.002	0.001
Chromium mg/l	0.054	0.056	0.020	0.020	0.005
Lead mg/l	0.002	0.100	0.150	0.003	0.006
Mercury mg/l	0.0005	0.0007	<0.0005	0.0008	<0.0005
Nitrite mg/l	0.3	2.3	<0.1	<0.1	0.3
Hydrocarbons mg/l	<0.001	<0.001	<0.001	<0.001	<0.001
Benzo-a-Pyrene mg/l	<0.001	<0.001	<0.001	<0.001	<0.001
Total Dissolved Solids	1300				
Color - Filter #1	97.0	98.0	94.5	95.5	98.5
Filter #2	95.0	96.5	91.0	91.0	98.0
Filter #3	85.5	89.5	77.5	78.5	83.5

>- Greater than

<- Less than

TABLE B-10

ANALYSES OF RUNOFF FROM SNOWMELT

NEAR WHITEMUD ROAD (EDMONTON)

Date	22/2/73	8/3/73	16/3/73	20/3/73	22/3/73	27/3/73
pH	7.0	7.4	7.3	7.3	7.5	7.3
Specific Conductance umho/cm	1080	1430	1220	650	800	1030
Hardness, Total mg/l	154	280	248	176	232	395
Alkalinity, Total mg/l	103	133	147	109	132	220
Sulfate mg/l	90	260	320	86	140	260
Chloride mg/l	265	295	41	83	100	42
Nitrate & Nitrite mg/l	0.5	1.4	1.4	2.3	1.6	5.0
Iron, Total mg/l	3.6	9.5	0.3	2.8	2.0	1.2
Calcium mg/l	47	70	66	52	55	108
Magnesium mg/l	9	26		11	23	30
Sodium mg/l	160	190	148	50	75	70
Potassium mg/l	6.1	8.0	8.9	2.0	13.0	12.0
Phosphate mg/l	2.0	3.1	2.8	2.1	3.3	1.5
Ammonia - N mg/l	0.6	1.1	1.4	2.3	1.3	1.0
Biochemical Oxygen Demand mg/l	3.5	26.0	34.0	10.0	12.0	50.0
Chemical Oxygen Demand mg/l	260	300	290	50	100	110
Oil and Grease mg/l	10.0	18.0	13.5	3.7	2.3	1.0
Phenols mg/l	0.020	0.021	0.007	0.001	0.009	0.003
Threshold Odor Number	16	8	8	4	4	8
Turbidity	15	>15	>15	>15	>15	>15
Total Solids mg/l	1200	1714	1862	796	920	760
Non-Filtrable Residue mg/l	530	690	450	205	250	116
Cobalt mg/l	0.014	0.038	0.043	0.018	0.002	0.001
Copper mg/l	0.015	0.036	0.034	0.016	0.001	0.062
Manganese mg/l	1.240	0.680	0.840	0.440	0.100	0.065
Nickel mg/l	0.038	0.063	0.052	0.046	0.036	0.048
Cadmium mg/l	0.0010	0.0042	0.0030	0.0010	0.0070	0.0070
Chromium mg/l	0.037	0.044	0.049	0.020	0.012	0.030
Lead mg/l	0.365	0.004	0.078	0.025	0.060	0.017
Mercury mg/l	0.0005	0.0005	0.0010	0.005	<0.0005	0.000
Nitrite mg/l	0.1	0.1	<0.1	0.4	0.5	0.1
Hydrocarbons mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Benzo-a-Pyrene mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Color - Filter #1	97.5	98.5	97.0	93.5	96.0	97.0
Filter #2	96.5	97.0	96.0	89.5	91.5	96.0
Filter #3	92.5	94.5	87.5	78.0	79.0	88.0

>- Greater than

<- Less than

TABLE B-11

ANALYSES OF RUNOFF FROM SNOWMELT

NORTHEAST END OF GROSVENOR BRIDGE (EDMONTON)

Date	22/2/73	8/3/73	14/3/73	16/3/73	20/3/73	22/3/73
pH	7.0	7.6	7.6	7.3	7.3	7.5
Specific Conductance umho/cm	1060	810	800	900	650	1050
Hardness, Total mg/l	175.5	175.5	232.0	180.0	146.0	206.0
Alkalinity, Total mg/l	107	106	122	101	84	102
Sulfate mg/l	78	210	100	170	72	110
Chloride mg/l	235	90	135	205	97	230
Nitrate & Nitrite mg/l	0.2	1.6	1.8	2.0	2.4	1.9
Iron, Total mg/l	4.7	1.8	2.6	0.1	1.4	2.1
Calcium mg/l	53.5	55.0	48.0	58.0	43.0	59.0
Magnesium mg/l	10.5	9.5	27.0	8.0	11.0	14.0
Sodium mg/l	155	105	80	150	50	160
Potassium mg/l	7.3	45.0	5.0	6.5	10.0	8.2
Phosphate mg/l	2.8	2.0	1.5	2.2	1.9	2.0
Ammonia - N mg/l	0.28	1.10	1.10	1.30	2.0	0.9
Biochemical Oxygen Demand mg/l	28	13	16	19	12	14
Chemical Oxygen Demand mg/l	240		87	115	70	60
Oil and Grease mg/l	8	9.03	2.4	3.9	2.4	1.6
Phenols mg/l	0.020	0.015	0.006	0.012	0.004	0.001
Threshold Odor Number	16	8	1	4	4	4
Turbidity	15	15	15	>15	>15	>15
Total Solids mg/l	1380	872	580	1286	640	840
Non-Filtrable Residue mg/l	508	275	60	468	136	290
Cobalt mg/l	0.014	0.022	0.015	0.042	0.020	0.003
Copper mg/l	0.028	0.032	0.010	0.015	0.013	0.008
Manganese mg/l	1.620	0.400	0.063	0.200	0.340	0.130
Nickel mg/l	0.039	0.054	0.034	0.054	0.024	0.064
Cadium mg/l	0.001	0.002	0.001	0.004	0.002	0.003
Chromium mg/l	0.057	0.026	0.010	0.014	0.012	0.024
Lead mg/l	0.400	0.005	0.002	0.020	0.025	0.015
Mercury mg/l	0.0005	0.0005	0.0005	0.0005	<0.0005	<0.0005
Nitrite mg/l	0.1	0.1	0.1	<0.1	0.6	<0.1
Total Dissolved Solids			520			
Color - Filter #1	97.5	99.0	97.5	98.5	96.0	97.5
Filter #2	97.0	98.5	97.0	96.0	94.0	94.5
Filter #3	94.0	96.0	91.5	89.0	84.0	85.0

>- Greater than

<- Less than

TABLE B-12

ANALYSIS OF RUNOFF FROM SNOWMELT

NORTHEAST END OF GROVE BRIDGE (EDMONTON)

Date	22/3/73	14/3/73	16/3/73	20/3/73	27/3/73	29/3/73
pH	7.1	8.2	7.5	7.3	7.3	7.5
Specific Conductance umho/cm	1160	1500	1275	550	1460	1450
Hardness, Total mg/l	182	324	318	160	450	352
Alkalinity, Total mg/l	123	208	207	111	302	265
Sulfate mg/l	80	200	350	175	440	250
Chloride mg/l	272	280	35	120	78	46
Nitrate & Nitrite mg/l	0.40	1.65	19.0	1.40	2.60	2.10
Iron, Total mg/l	4.0	23.0	0.6	2.8	2.0	1.7
Calcium mg/l	60	55	79	48	140	56
Magnesium mg/l	8.0	45.5	29.0	10.0	24.0	52.0
Sodium mg/l	175	190	140	130	115	115
Potassium mg/l	8.0	19.0	18.0	5.0	16.0	13.0
Phosphate mg/l	3.2	3.4	3.3	2.8	0.8	0.9
Ammonia - N mg/l	0.32	2.60	3.50	2.40	1.20	1.50
Biochemical Oxygen Demand mg/l	68	44	27	16	<0.1	6
Chemical Oxygen Demand mg/l	355	286	185	20	130	49
Oil and Grease mg/l	17.0	7.1	8.5	4.4	1.9	3.7
Phenols mg/l	0.03	0.011	0.009	0.001	0.001	0.014
Threshold Odor Number	16	8	8	8	8	4
Turbidity	15	15	15	15	15	15
Total Solids mg/l	1540	1590	1684	968	1180	1108
Non-Filtrable Residue mg/l	800	620	670	472	46	56
Cobalt mg/l	0.016	0.045	0.034	0.001	0.062	0.011
Copper mg/l	0.035	0.036	0.022	0.026	0.011	0.013
Manganese mg/l	1.580	0.300	0.560	1.044	0.420	0.033
Nickel mg/l	0.054	0.160	0.042	0.017	0.025	0.014
Cadmium mg/l	0.001	0.026	0.001	0.004	0.001	<0.001
Chromium mg/l	0.065	0.063	0.013	0.022	0.006	0.008
Lead mg/l	0.445	0.009	0.032	0.300	0.019	0.012
Mercury mg/l	0.0005	<0.0005	<0.0005	0.0005	<0.0005	<0.0005
Nitrite mg/l	0.90	0.05	<0.10	0.10	<0.1	<0.1
Hydrocarbons mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Benzo-a-Pyrene mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Color - Filter #1	98.0	89.0	98.0	94.5	97.0	97.5
Filter #2	98.0	87.0	96.0	92.5	97.0	97.5
Filter #3	94.0	77.0	87.5	79.5	92.0	92.0

<- Less than

TABLE B-13

ANALYSIS OF RUNOFF FROM SNOWMELT

WHITEMUD CREEK NEAR ASPEN DRIVE (EDMONTON)

Date	14/3/73	16/3/73	20/3/73	22/3/73	27/3/73	29/3/73
pH	7.5	7.2	7.2	7.4	7.4	7.1
Specific Conductance umho/cm	1050	760	375	370	450	400
Hardness, Total mg/l	273	158	86	128	142	118
Alkalinity, Total mg/l	132	84	65	66	92	78
Sulfate mg/l	160	150	60	165	98	52
Chloride mg/l	185	165	46	40	34	26
Nitrate & Nitrite mg/l	3.1	1.8	2.7	1.2	2.1	1.7
Iron, Total mg/l	3.8	0.1	2.6	4.0	2.3	7.5
Calcium mg/l	69	50	28	31	40	35
Magnesium mg/l	25	8	4	12	10	7
Sodium mg/l	115	140	30	30	32	26
Potassium mg/l	9.2	11.0	9.0	9.4	16.0	6.0
Phosphate mg/l	3.5	3.3	2.9	4.4	3.1	1.8
Ammonia - N mg/l	4.0	2.0	1.9	1.1	0.5	0.7
Biochemical Oxygen Demand mg/l	26	30	0	24	11	9
Chemical Oxygen Demand mg/l	150	190	100	110	130	10
Oil and Grease mg/l	5.0	10.6	5.0	5.0	2.0	4.6
Phenols mg/l	1.000	0.013	0.030	0.013	0.056	0.039
Threshold Odor Number	2	8	8	4	8	4
Turbidity	15	15	15	15	15	15
Total Solids mg/l	932	996	814	620	1440	672
Non-Filtrable Residue mg/l	140	528	340	360	928	396
Cobalt mg/l	0.030	0.040	0.012	0.001	0.002	0.009
Copper mg/l	0.030	0.014	0.016	0.015	0.060	0.027
Manganese mg/l	0.073	0.200	0.460	0.044	0.090	0.053
Nickel mg/l	0.034	0.046	0.028	0.019	0.066	0.106
Cadmium mg/l	0.001	0.001	0.001	0.003	0.005	<0.001
Chromium mg/l	0.028	0.013	0.030	0.019	0.067	0.056
Lead mg/l	0.002	0.018	0.021	0.060	0.004	0.008
Mercury mg/l	0.0005	<0.0005	0.0005	<0.0005	0.0005	0.0005
Nitrite mg/l	2.1	0.4	0.2	<0.1	<0.1	<0.1
Hydrocarbons mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Benzo-a-Pyrene mg/l	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Total Dissolved Solids	790					
Color - Filter #1	95.5	95.0	96.0	94.0	86.0	94.5
Filter #2	93.0	92.0	93.0	90.0	82.0	89.5
Filter #3	83.0	82.0	80.5	77.5	64.0	71.5

>- Greater than

<- Less than

TABLE B-14

ANALYSIS OF RUNOFF FROM SNOWMELT

GOVERNMENT HOUSE PARK (EDMONTON)

Date	22/2/73	29/2/73	14/3/73	16/3/73	20/3/73	27/3/73
pH	7.1	7.5	8.2	7.5	7.3	7.3
Specific Conductance umho/cm	1160	1450	1500	1275	550	1460
Hardness, Total mg/l	182	352	324	318	160	450
Alkalinity, Total mg/l	123	265	208	207	111	302
Sulfate mg/l	80	250	200	350	175	440
Chloride mg/l	272	46	280	35	120	78
Nitrate & Nitrite mg/l	0.40	2.10	1.65	19.00	1.40	2.60
Iron, Total mg/l	4.0	1.7	23.0	0.6	2.8	2.0
Calcium mg/l	60	56	55	79	48	140
Magnesium mg/l	8	52	45.5	29	10	24
Sodium mg/l	175	115	190	140	130	115
Potassium mg/l	8.0	13.0	19.0	18.0	5.0	16.0
Phosphate mg/l	3.2	0.9	3.4	3.3	2.8	0.8
Ammonia - N mg/l	0.32	1.5	2.6	3.5	2.4	1.2
Dissolved Oxygen mg/l	68	6	24	27	16	<0.1
Biochemical Oxygen Demand mg/l	68	6	24	27	16	<0.1
Chemical Oxygen Demand mg/l	355	49	280	185	20	150
Oil and Grease mg/l	17.0	3.7	7.1	8.5	4.4	1.9
Phenols mg/l	0.030	0.014	0.011	0.009	0.001	0.001
Threshold Odor Number	16	4	8	8	8	8
Turbidity	15	15	15	15	15	15
Total Solids mg/l	1540	1108	1590	1684	768	1180
Non-Filtrable Residue mg/l	800	56	620	670	472	46
Cobalt mg/l	0.016	0.011	0.045	0.034	0.001	0.062
Copper mg/l	0.035	0.013	0.036	0.022	0.026	0.011
Manganese mg/l	1.58	0.033	0.300	1.560	0.044	0.420
Nickel mg/l	0.054	0.014	0.160	0.042	0.017	0.025
Cadmium mg/l	0.001	0.001	0.026	0.001	0.004	0.001
Chromium mg/l	0.065	0.009	0.063	0.013	0.022	0.006
Lead mg/l	0.445	0.012	0.009	0.032	0.300	0.019
Mercury mg/l	0.0005	0.0005	<0.0005	<0.0005	0.0005	<0.0005
Nitrite mg/l	0.9	0.1	0.05	<0.1	0.1	<0.1
Total Dissolved Solids			970			
Color - Filter #1	98.0	97.5	89.0	98.0	94.5	97.0
Filter #2	98.0	97.5	87.0	96.0	92.5	97.0
Filter #3	94	92.0	77.0	87.5	79.5	92.0

< Less than

TABLE B-15

SNOWMELT RUNOFF THROUGH A COMBINED SEWER - DAWSON BRIDGE

	April 3
Biochemical Oxygen Demand mg/l	263
Chemical Oxygen Demand mg/l	588
pH	9.4
Alkalinity PP (as $CaCO_3$) mg/l	51
Alkalinity Total (as $CaCO_3$)	193
Threshold Odor Type	Stale sewage
Threshold Odor Number	500
Total Residue mg/l	1050
Ignition Loss mg/l	404
Non-Filtrable Residue mg/l	440
Ignition Loss mg/l	180
Oils and Grease mg/l	25.0
Phenols ug/l	190
Chlorides mg/l	60
Total Phosphorous mg/l	50.0
Ammonia Nitrogen (NH_3-N) mg/l	16.0
Nitrate Nitrogen (NO_3-N) mg/l	0.6
Sulphates mg/l	100
Total Coliforms per 100 ml	350
E. Coli per 100 mls	Negative
Standard Plate Count per ml	3,000,000

APPENDIX C

ANALYSES OF RUNOFF FROM RAINFALL

TABLE C-1

ANALYSES OF RUNOFF FROM RAINFALL

MAYFAIR PARK (EDMONTON)

May 14, 1969

Time of Day	BOD-5-20 mg/l	Total Solids mg/l
10:12	7.4	355
10:34	9.7	373
11:05	9.2	339
11:32	9.0	491

TABLE C-2

ANALYSES OF RUNOFF FROM RAINFALL

GOVERNMENT HOUSE PARK (EDMONTON)

May 25, 1969

Time of Day	Flows cfs	BOD-5-20 mg/l	Total Solids mg/l	Conductivity umho @ 25°C
05:45	8	79	2034	374
05:55		60	1589	458
06:05	19	66	1540	541
06:17	39	57	1770	370
06:34	56	51	1847	317
06:47	75	39	1298	315
07:00	75	35	1396	325
07:15		25	969	229
07:30	75	24	903	236
08:00	39	22	803	206
08:30	19	18	843	248

TABLE C-3

ANALYSES OF RUNOFF FROM RAINFALL

GOVERNMENT HOUSE PARK (EDMONTON)

May 27, 1969

Time of Day	Flows cfs	BOD-5-20 mg/l	Total Solids mg/l	Total Volatile Solids mg/l	Total Fixed Solids mg/l	Conductivity umho @ 25°C
08:25	0.7	>35				720
08:35	1.3	>35	1950	464	1486	648
08:40	1.3					
08:45		>35	2352	520	1832	517
08:55	2.3	35	1780	406	1374	595
09:15	2.3					
09:21		32	1582	336	1246	971
09:25	3.3					
09:31		26	1356	286	1070	969
09:41		25	1284	260	1024	1056
10:01		28	1332	262	1670	1019
10:26		28	1290	242	1048	930
10:35	3.3					
10:55		28	1380	292	1088	888
11:35	1.3	>35	1484	294	1190	1042

>- Greater than

TABLE C-4

ANALYSES OF RUNOFF FROM RAINFALL

GOVERNMENT HOUSE PARK (EDMONTON)

June 6, 1969

Time of Day	Flows cfs	BOD-5-20 mg/l	Total Solids mg/l	Total Volatile Solids mg/l	Total Fixed Solids mg/l	Conductivity umho @ 25°C
03:33	3.2	95	2596	502	2094	926
03:46	7.7	62	1184	272	912	376
04:01	7.7	68				351
04:21	.5	63				828
04:40	26	>63				947
05:05	26	>63	596	164	432	789
05:30	15	>63	968	234	734	686
06:05	11	58				553
06:50	5	61				585
07:30	3.2					
08:00	1.8					

>- Greater than

TABLE C-5

ANALYSES OF RUNOFF FROM RAINFALL

GOVERNMENT HOUSE PARK (EDMONTON)

June 6, 1969

Time of Day	Flows cfs	BOD-5-20 mg/l	Total Solids mg/l	Total Volatile Solids mg/l	Total Fixed Solids mg/l
14:15	170	60	3074	436	2638
14:30	212	52	3482	400	3087
14:46	128	64	4092	520	3572
15:05	66	57	4170	526	3644
15:30	11	58	4192	470	3722

TABLE C-6

ANALYSES OF RUNOFF FROM RAINFALL

GOVERNMENT HOUSE PARK (EDMONTON)

June 23, 1969

Time of Day	Flows cfs	BOD-5-20 mg/l	Total Solids mg/l	Total Volatile Solids mg/l	Total Fixed Solids mg/l	Suspended Solids mg/l	Volatile Suspended Solids mg/l	Conductivity umho @ 25°C
11:40	13	68	2604	522	2082	2196	2196	322
11:55	25	92	1918	438	1480	1410	1410	494
12:10	16	108	2046	558	1488	581	1146	581
12:40	17	92				704	1054	704

TABLE C7

ANALYSIS OF RUNOFF FROM RAINFALL

GOVERNMENT HOUSE PARK (EDMONTON)

July 16, 1969

Time	Flow cfs	BOD-5-20 mg/l	Total Solids mg/l	Total Volatile Solids mg/l	Fixed Solids mg/l	Suspended Solids mg/l	Volatile Suspended Solids mg/l	Fixed Suspended Solids mg/l	Conductivity umho @ 25°C
19:59	4	54	2366	422	1944	2024	332	1692	272
20:15	3	62	1766	312	1451	1200	186	912	310
20:40	135	44	1262	262	1000	908	154	754	378
21:20	115	30	1488	228	1260	1096	192	1008	269
21:55	12	24	1574	228	1146	1420	256	1164	220

Time	NO_3 mg/l	NH_3 mg/l	Cl mg/l	SO_4 mg/l	pH	Total Hardness mg/l as $CaCO_3$	Total Alkalinity mg/l as $CaCO_3$	Oils & Greases mg/l	Pesticides mg/l	Herbicides mg/l
19:59	0.445	7.1	25	38	--	86	--	4.2	0	7
20:15	0.175	1.5	14	44	7.3	106	20	2.7		
20:40	0.245	0.95	6	85	7.3	154	24	4.3		
21:20	0.285	1.0	7	54	7.1	96	18	2.6		15.5
21:55	0.295	0.8	9	31	7.3	74	18	5.1		

TABLE C-8

ANALYSES OF RUNOFF FROM RAINFALL (EDMONTON 1971)

	Kennedale (Aug 3)	Groat Bridge (Sept 19)	Groat Bridge (Sept 19)	Kennedale Ravine (Sept 19)
Calcium mg/l	158	114	58	58
Magnesium mg/l	72	49	15	28
Total Hardness ($CaCO_3$) mg/l	689	486	206	259
pH at 78°F	7.1	7.2	7.3	6.8
Bicarbonate mg/l	276	246	161	120
Total Alkalinity ($CaCO_3$) mg/l	226	202	132	98
Total Dissolved Solids				
Dried at 105°C mg/l	1272	792	300	536
Ignited at 550°C mg/l	908	600	172	388
Total Suspended Solids				
Dried at 105°C mg/l	19	674	381	221
Ignited at 550°C mg/l	9	508	298	161
Nitrate as mg/l Nitrogen	0.41	0.50	0.1	1.36
Inorganic Ammonium and Organic Nitrogen Compounds mg/l as Nitrogen	0.74	1.04	11.2	0.63
Dissolved Phosphate as Phosphorous mg/l	0.02	0.06	0.06	0.11
Total Phosphorous	0.05	4.01	0.17	0.21
Organic Carbon mg/l	41	159	56	43
Inorganic Carbon mg/l	43	61	29	21
Total Carbon mg/l	84	220	85	64
Total Solids	19	674	381	221
Volatile Soilds and Ignition Loss mg/l	10	166	83	60
Iron as Fe_2O_3 mg/l	1.1	40	23	13

TABLE C-8 (Continued)

	Kennedale (Aug 3)	Groat Bridge (Sept 19)	Groat Bridge (Sept 19)	Kennedale Ravine (Sept 19)
Silica mg/l	8	302	136	103
Remainder mg/l	-----	166	139	45

SUSPENDED SOLIDS SETTLING RATE (PERCENT)

Time				
5 Minutes	20	38	29	38
15 Minutes	37	59	43	50
30 Minutes	54	75	52	56
1 Hour	71	81	62	63
2 Hours	74	91	76	78

NOTE: Settled samples taken from midpoint of a 500 ml graduated cylinder (depth 10.9 inches)

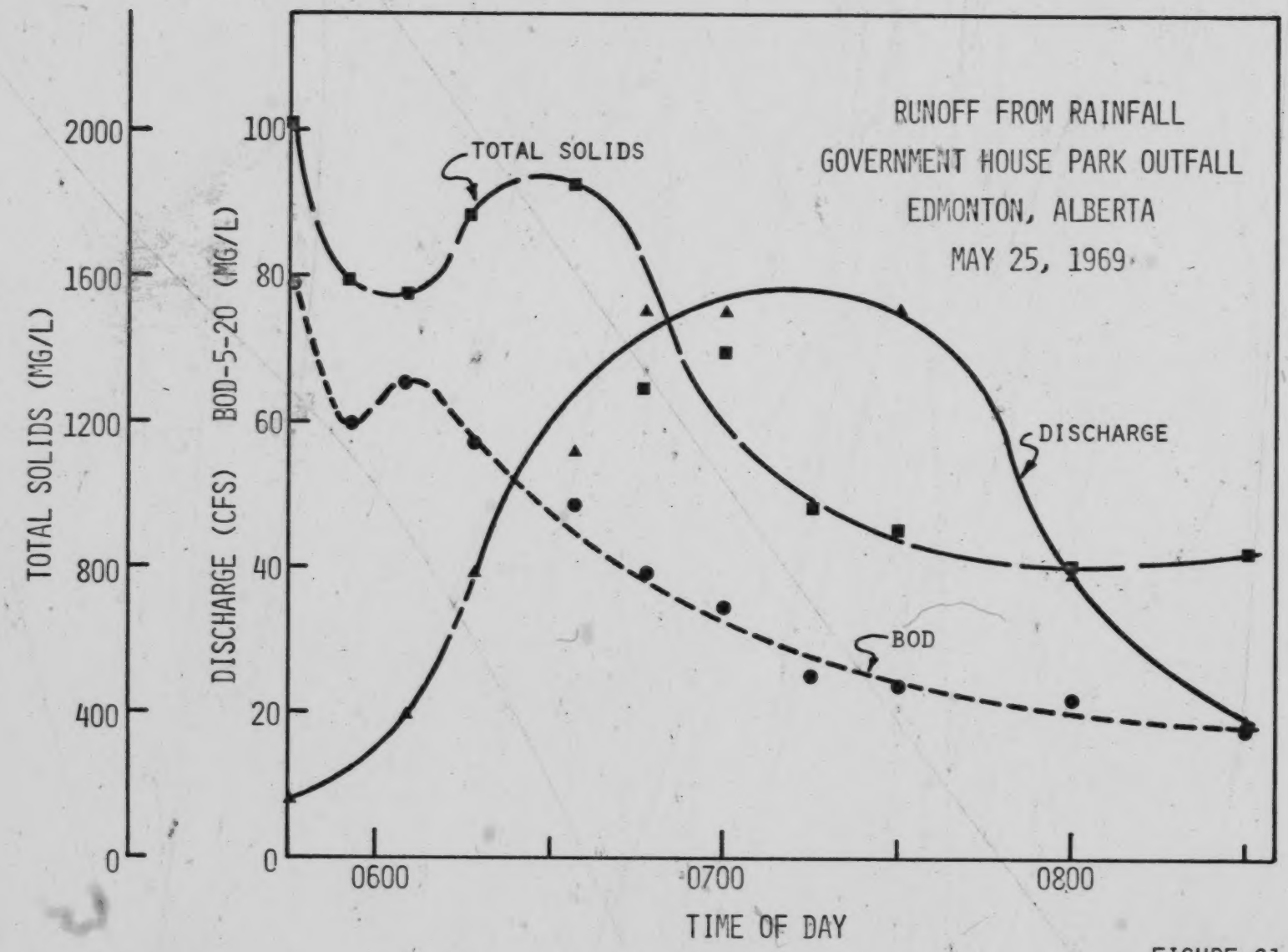

RUNOFF FROM RAINFALL
GOVERNMENT HOUSE PARK OUTFALL
EDMONTON, ALBERTA
MAY 25, 1969
TOTAL SOLIDS
DISCHARGE
BOD
TOTAL SOLIDS (MG/L)
DISCHARGE (CFS) BOD-5-20 (MG/L)
2000
1600
1200
800
400
0
100
80
60
40
20
0
0600
0700
0800
TIME OF DAY

FIGURE C1

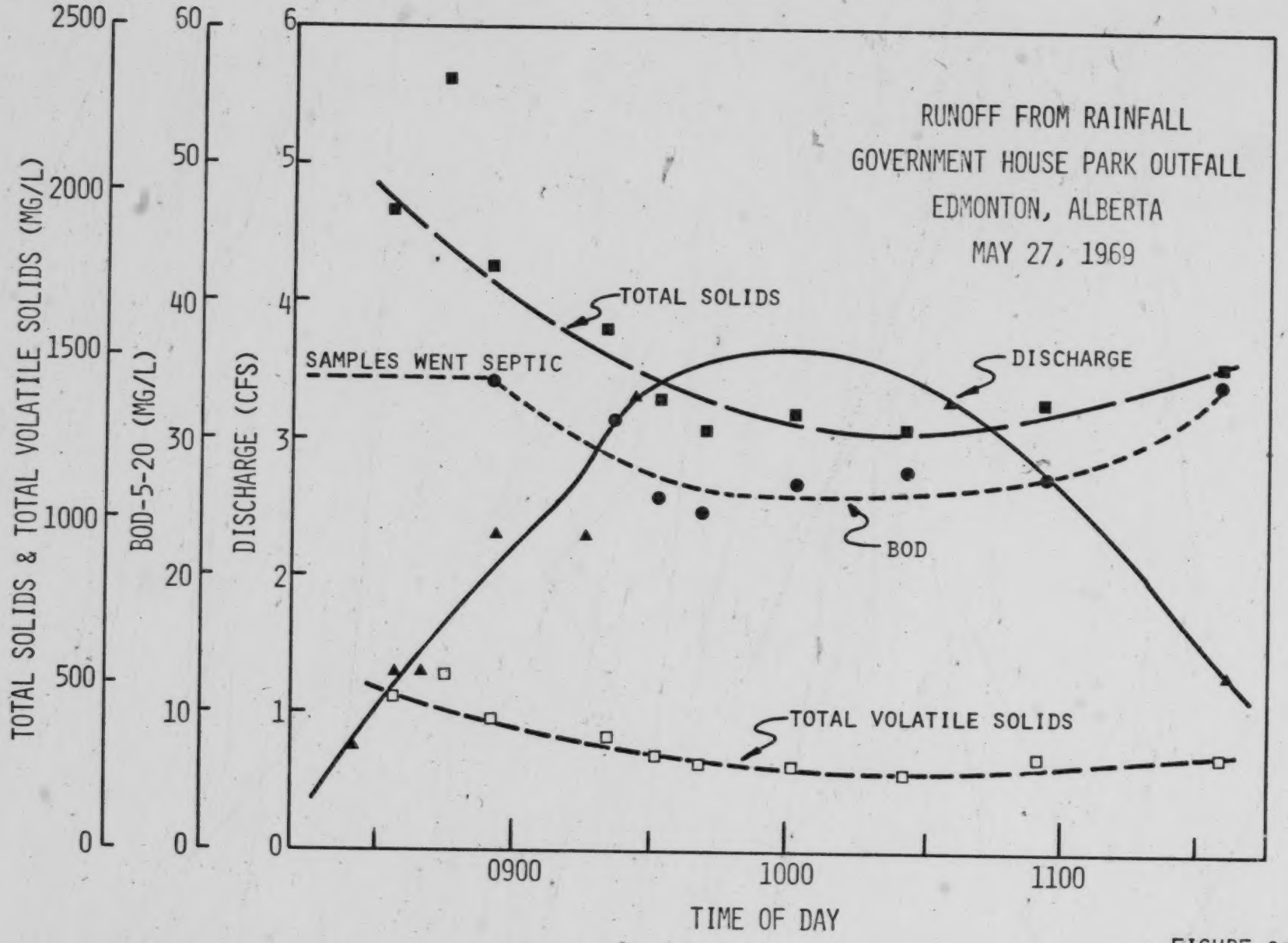

RUNOFF FROM RAINFALL
GOVERNMENT HOUSE PARK OUTFALL
EDMONTON, ALBERTA
MAY 27, 1969
TOTAL SOLIDS
SAMPLES WENT SEPTIC
DISCHARGE
BOD
TOTAL VOLATILE SOLIDS
TOTAL SOLIDS & TOTAL VOLATILE SOLIDS (MG/L)
BOD-5-20 (MG/L)
DISCHARGE (CFS)
TIME OF DAY
0900
1000
1100
2500
2000
1500
1000
500
0
60
50
40
30
20
10
0
6
5
4
3
2
1
0

FIGURE C2

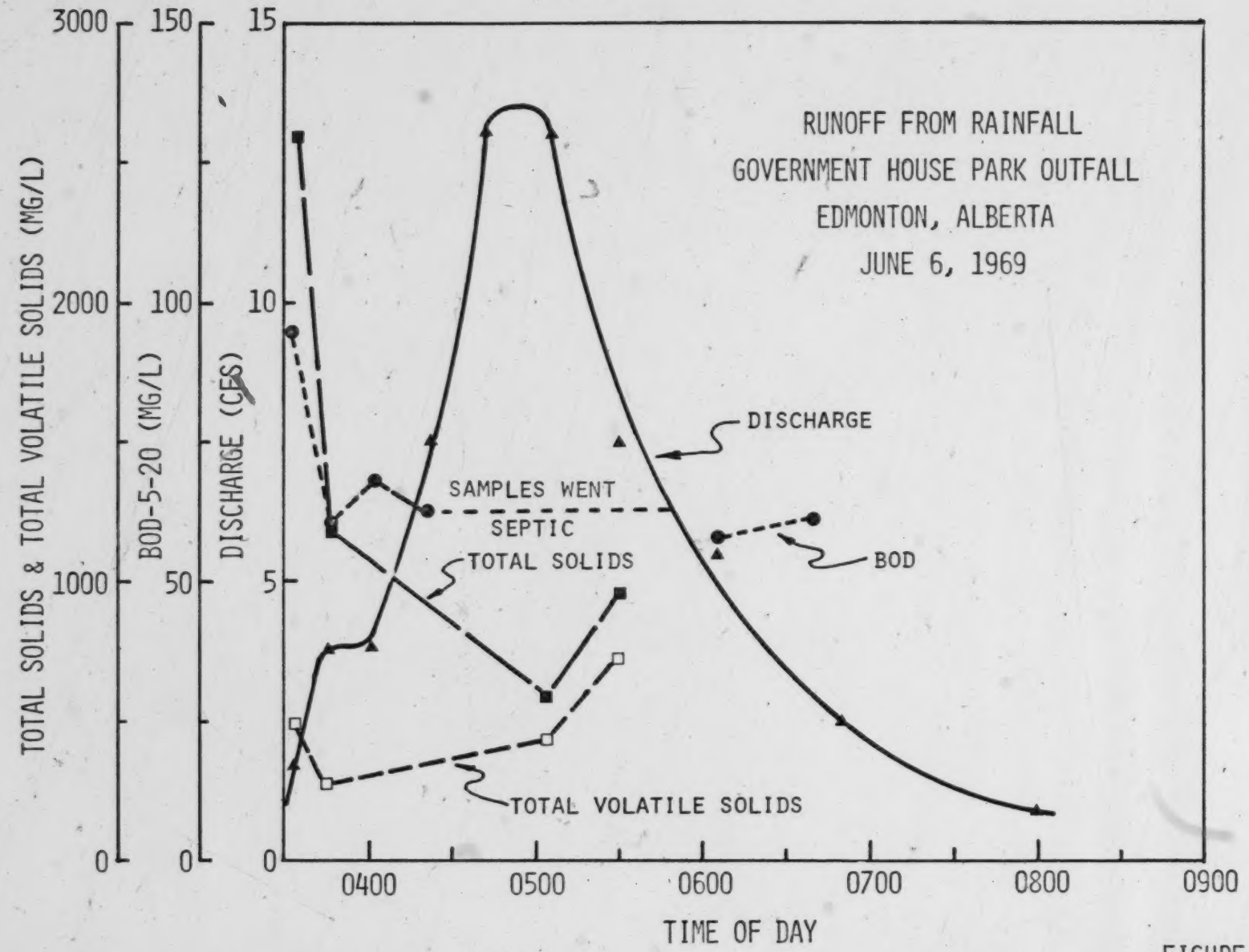

RUNOFF FROM RAINFALL
GOVERNMENT HOUSE PARK OUTFALL
EDMONTON, ALBERTA
JUNE 6, 1969
TOTAL SOLIDS & TOTAL VOLATILE SOLIDS (MG/L)
BOD-5-20 (MG/L)
DISCHARGE (CFS)
3000
2000
1000
0
150
100
50
0
15
10
5
0
DISCHARGE
SAMPLES WENT SEPTIC
TOTAL SOLIDS
BOD
TOTAL VOLATILE SOLIDS
0400
0500
0600
0700
0800
0900
TIME OF DAY

FIGURE C3

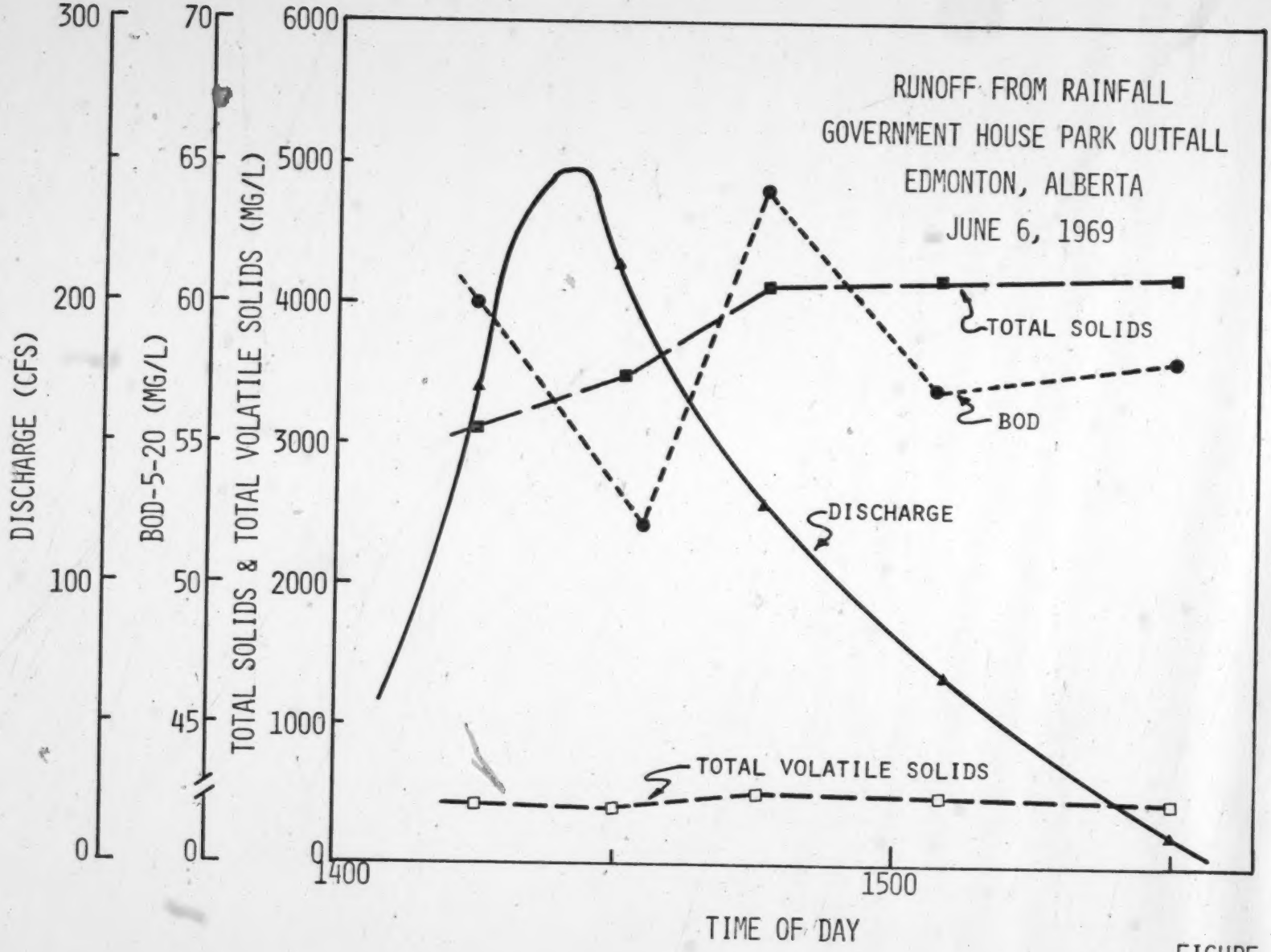

RUNOFF FROM RAINFALL
GOVERNMENT HOUSE PARK OUTFALL
EDMONTON, ALBERTA
JUNE 6, 1969
DISCHARGE (CFS)
BOD-5-20 (MG/L)
TOTAL SOLIDS & TOTAL VOLATILE SOLIDS (MG/L)
300
200
100
0
70
65
60
55
50
45
0
6000
5000
4000
3000
2000
1000
0
TOTAL SOLIDS
BOD
DISCHARGE
TOTAL VOLATILE SOLIDS
1400
1500
TIME OF DAY

FIGURE C4

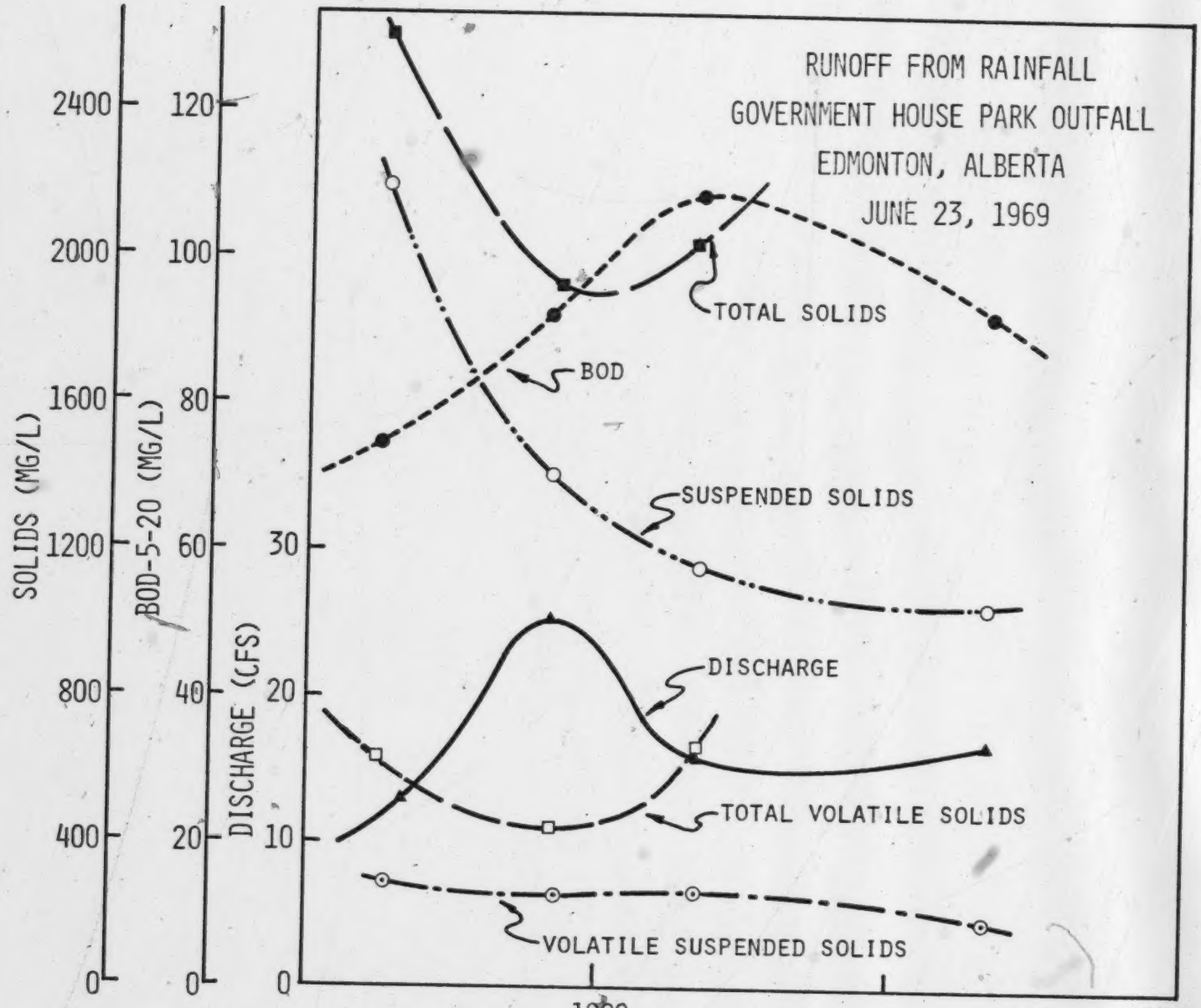

RUNOFF FROM RAINFALL
GOVERNMENT HOUSE PARK OUTFALL
EDMONTON, ALBERTA
JUNE 23, 1969
TOTAL SOLIDS
BOD
SUSPENDED SOLIDS
DISCHARGE
TOTAL VOLATILE SOLIDS
VOLATILE SUSPENDED SOLIDS
SOLIDS (MG/L)
BOD-5-20 (MG/L)
DISCHARGE (CFS)
2400
2000
1600
1200
800
400
0
120
100
80
60
40
20
0
30
20
10
0
1200
1300
TIME OF DAY

FIGURE C5

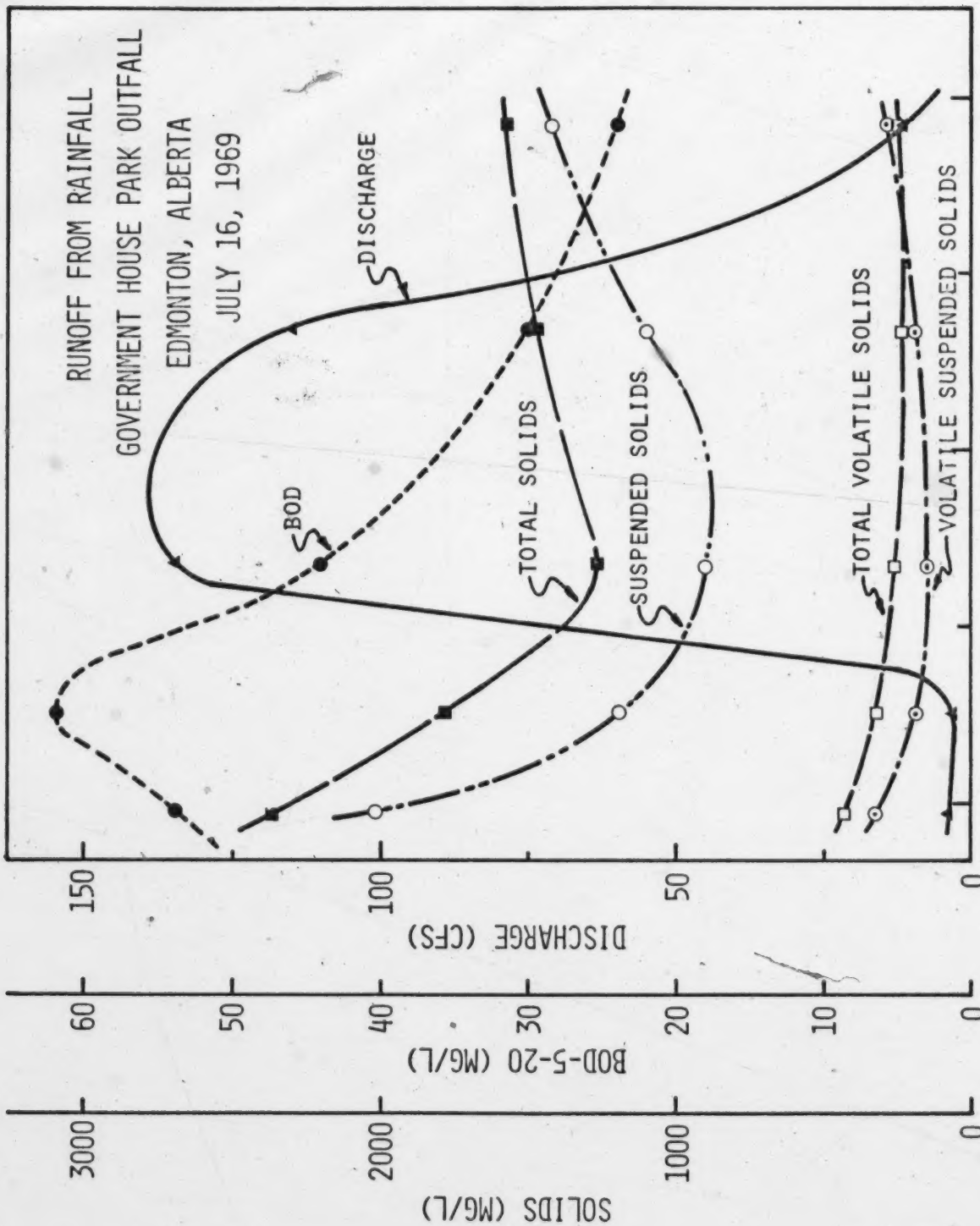

RUNOFF FROM RAINFALL
GOVERNMENT HOUSE PARK OUTFALL
EDMONTON, ALBERTA
JULY 16, 1969
DISCHARGE
BOD
TOTAL SOLIDS
SUSPENDED SOLIDS
TOTAL VOLATILE SOLIDS
VOLATILE SUSPENDED SOLIDS
DISCHARGE (CFS)
BOD-5-20 (MG/L)
SOLIDS (MG/L)
TIME OF DAY
2000
2100
2200
0
50
100
150
10
20
30
40
50
60
1000
2000
3000

FIGURE C6

APPENDIX D

ANALYSES OF COMBINED SEWER OVERFLOW

TABLE D-1

ANALYSES OF COMBINED SEWAGE OVERFLOWS

EDMONTON NO. 3 SEWAGE TREATMENT PLANT

May 13, 1969

Time of Day	BOD-5-20 mg/l	Total Solids mg/l
16:02	>350	1628
16:11	200	1117
16:24	175	786
16:34	140	496
16:45	100	857
16:54	160	1975
17:03	290	1849
17:19	180	1265

>- Greater than

TABLE D-2

ANALYSES OF COMBINED SEWAGE OVERFLOWS

EDMONTON NO. 3 SEWAGE TREATMENT PLANT

May 27, 1969

Time of Day	BOD-5-20 mg/l	Total Solids mg/l	Total Volatile Solids mg/l	Total Fixed Solids mg/l
11:55	137	1644	420	1224
12:05	152	1330	418	912
12:16	160	1358	418	940
12:27	137	1446	436	1010
12:38	127	1316	342	974
12:51	95	908	254	654
13:09	107	804	266	574

TABLE D-3

ANALYSES OF COMBINED SEWAGE OVERFLOWS

EDMONTON MAIN SEWAGE TREATMENT PLANT

May 29, 1969

Time of Day	Flows Bypassed cfs	BOD-5-20 mg/l	Total Solids mg/l	Total Volatile Solids mg/l	Total Fixed Solids mg/l
19:10	17	313	1192	590	602
19:20	23	273	964	434	530
19:30	20	315	1020	552	468
19:40	32	264	1092	606	486
19:50	34	307	1224	646	578
20:00	29	236	1448	676	772
20:15	22	250	1326	642	684
20:30	17	213	1368	582	786
20:45	14	192	1188	504	684
21:00	13	225	1572	670	902
21:30	12	212	1390	646	744

TABLE D-4

ANALYSES OF COMBINED SEWAGE OVERFLOWS

EDMONTON MAIN SEWAGE TREATMENT PLANT

May 30, 1969

Time of Day	Flows Bypassed cfs	BOD-5-20 mg/l	Total Solids mg/l	Total Volatile Solids mg/l	Total Fixed Solids mg/l
14:00	6	263	678	156	522
14:10	6	328	788	224	564
14:20	6	310	760	206	554
14:30	7	273	756	222	534
15:00	13	243	716	156	560
15:30	26	181	660		
16:00	28	177	1030	232	798
16:30	32	178			
17:00	77	178	1014	400	614
17:30	80	198			
18:00	80	112	2486	460	2026
19:00	20	133	1816	220	1596
20:30	5	155	990	190	800

- Greater than

TABLE D-5

ANALYSES OF COMBINED SEWAGE OVERFLOWS

EDMONTON MAIN SEWAGE TREATMENT PLANT

June 6, 1969

Time of Day	BOD-5-20 mg/l	Total Solids mg/l	Total Volatile Solids mg/l	Total Fixed Solids mg/l
04:30	193	650	248	402
05:00	299	1456	596	860
05:30	262	1878	1056	822
06:00	283	1688	614	1074
06:30	177	1446	534	912
07:00	169	1594	506	1088
07:30	199	1750	562	1188

TABLE D-6

ANALYSES OF COMBINED SEWAGE OVERFLOWS

EDMONTON MAIN SEWAGE TREATMENT PLANT

June 6, 1969

Time of Day	BOD-5-20 mg/l	Total Solids mg/l	Total Volatile Solids mg/l	Total Fixed Solids mg/l
16:00	313	2630	892	1738
16:30	297	1994	712	1282
17:00	268	2344	776	1568
17:30	219	1406	406	1000
18:00	237	1332	388	944
18:30	217	1164	332	832
19:00	263	1072	358	714

TABLE D-7

ANALYSES OF COMBINED SEWAGE OVERFLOWS

EDMONTON MAIN SEWAGE TREATMENT PLANT

June 23, 1969

Time of Day	BOD-5-20 mg/l	Total Solids mg/l	Total Volatile Solids mg/l	Total Fixed Solids mg/l	Conductivity umho @ 25°C
12:30	375				1080
12:40	407	994	468	526	1041
12:50	392				1062
13:00	378				1047
13:20	375	1720	736	984	779
13:40	365				708
14:20	365	1906	800	1106	637
15:00	189				387
15:20	151	1424	388	1036	374
15:40	175				385

TABLE D-8

COMBINED SEWER OVERFLOW

EDMONTON MAIN SEWAGE TREATMENT PLANT - JULY 16, 1969

Time pm	BOD-5-20 mg/l	Total Solids mg/l	Total Volatile Solids mg/l	Total Fixed Solids mg/l	Conductivity mho @25° C	pH	NO_3 mg/l	NH_3 mg/l	Cl mg/l	Total Hardness mg/l @$CaCO_3$	Total Alkalinity mg/l @$CaCO_3$	SO_4 mg/l
20:30	330	1156	502	654	697	7.2	0.02	14.7	39	166	73	60
21:00	342	1460	654	806	484	7.0	0.04	6.0	25	130	65	42
21:30	204	1026	360	666	333	7.0	0.02	17.0	23	102	48	39

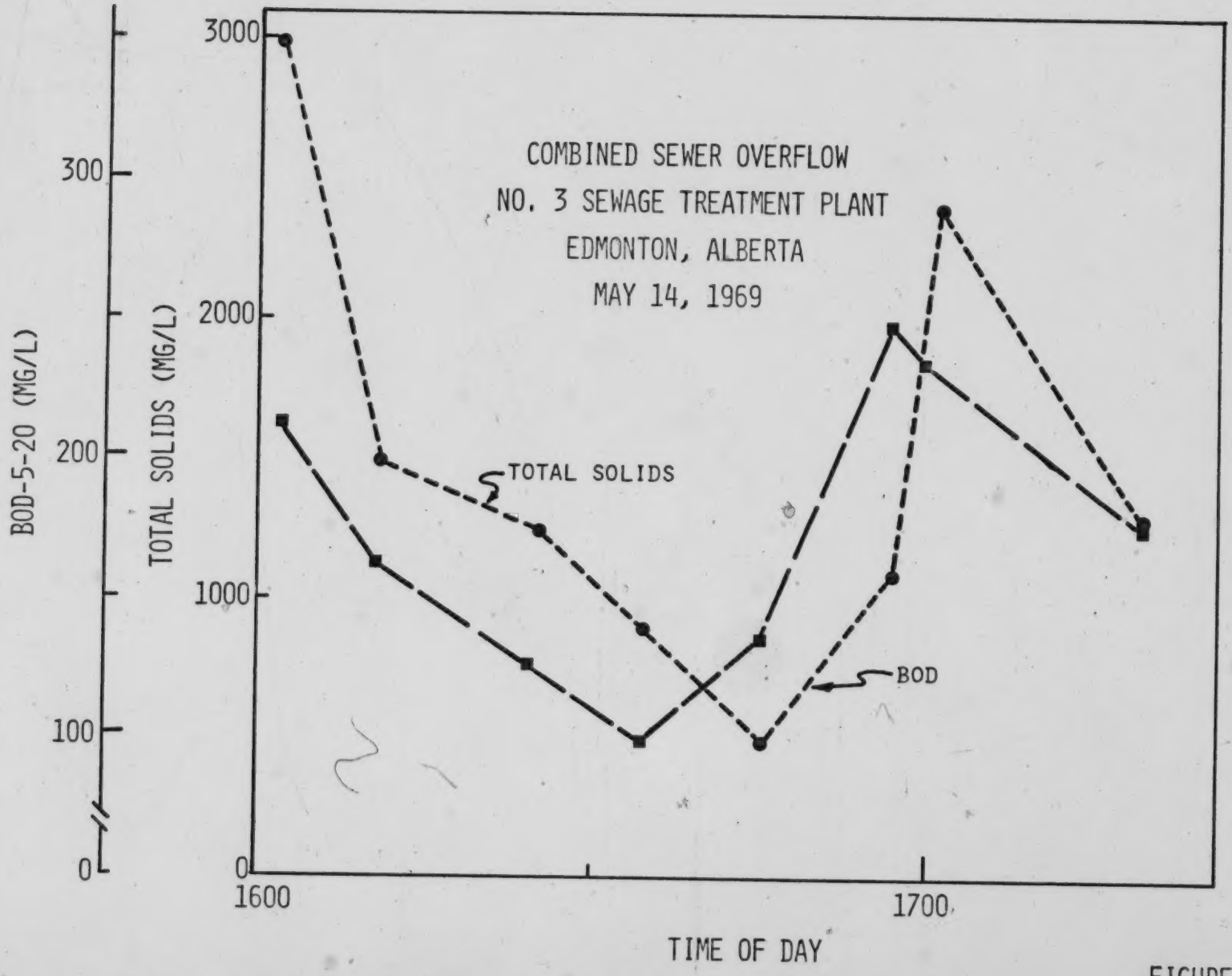

COMBINED SEWER OVERFLOW
NO. 3 SEWAGE TREATMENT PLANT
EDMONTON, ALBERTA
MAY 14, 1969
TOTAL SOLIDS
BOD
BOD-5-20 (MG/L)
TOTAL SOLIDS (MG/L)
300
200
100
0
3000
2000
1000
0
1600
1700
TIME OF DAY

FIGURE D1

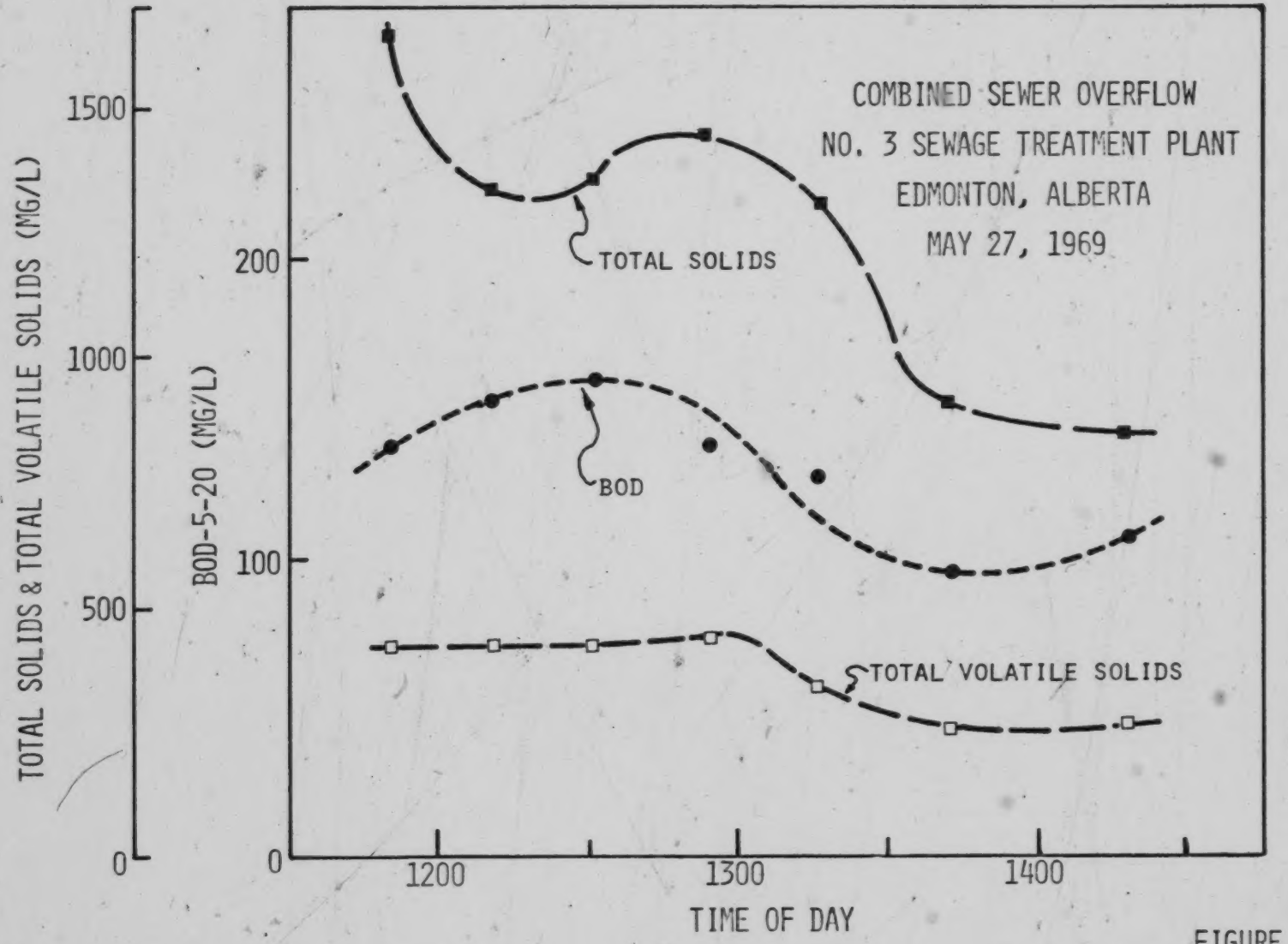

COMBINED SEWER OVERFLOW
NO. 3 SEWAGE TREATMENT PLANT
EDMONTON, ALBERTA
MAY 27, 1969
TOTAL SOLIDS
BOD
TOTAL VOLATILE SOLIDS
TOTAL SOLIDS & TOTAL VOLATILE SOLIDS (MG/L)
BOD-5-20 (MG/L)
1500
1000
500
0
200
100
0
1200
1300
1400
TIME OF DAY

FIGURE D2

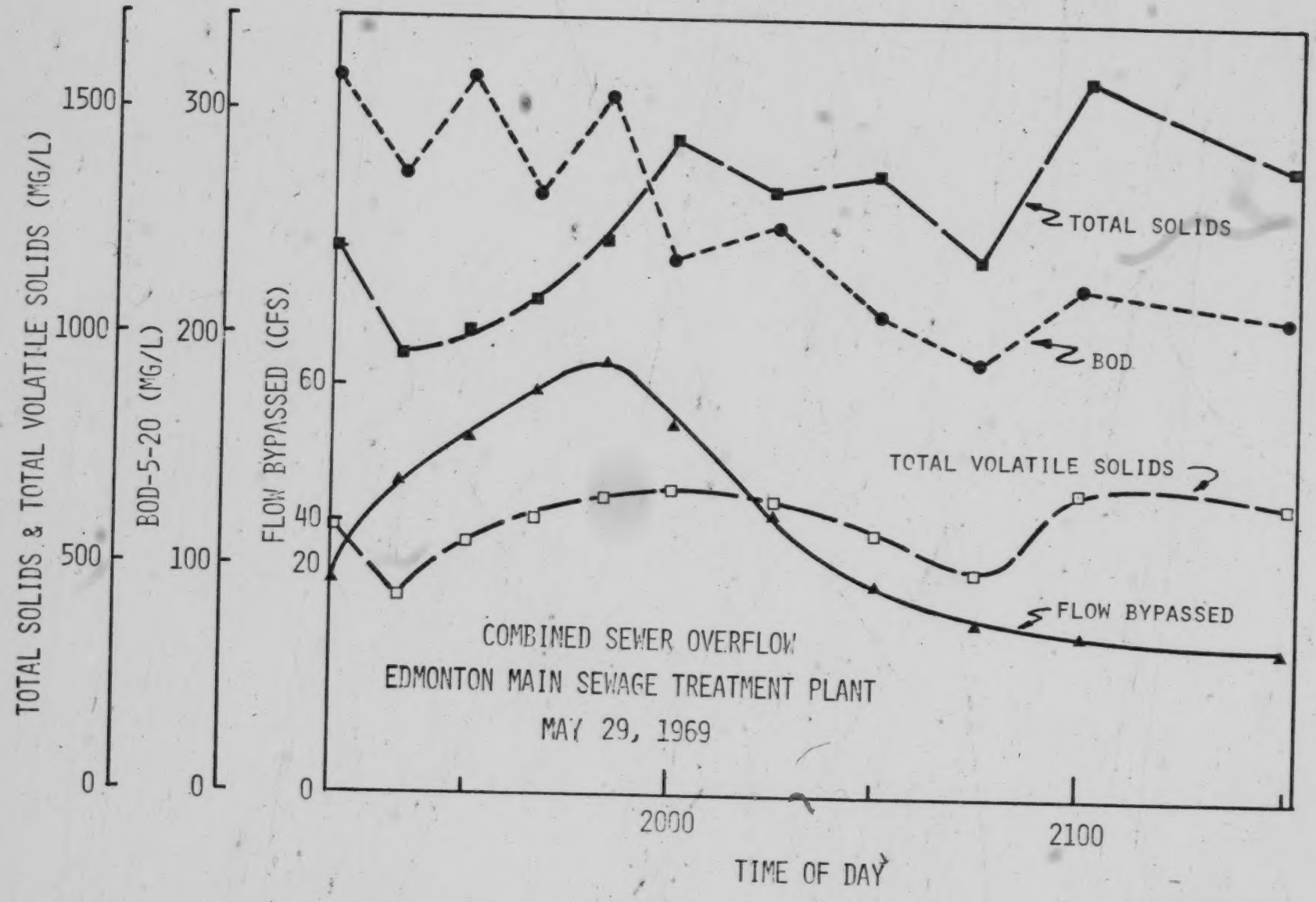

TOTAL SOLIDS & TOTAL VOLATILE SOLIDS (MG/L)
1500
1000
500
0
BOD-5-20 (MG/L)
300
200
100
0
FLOW BYPASSED (CFS)
60
40
20
0
TOTAL SOLIDS
BOD
TOTAL VOLATILE SOLIDS
FLOW BYPASSED
COMBINED SEWER OVERFLOW
EDMONTON MAIN SEWAGE TREATMENT PLANT
MAY 29, 1969
2000
2100
TIME OF DAY

FIGURE D3

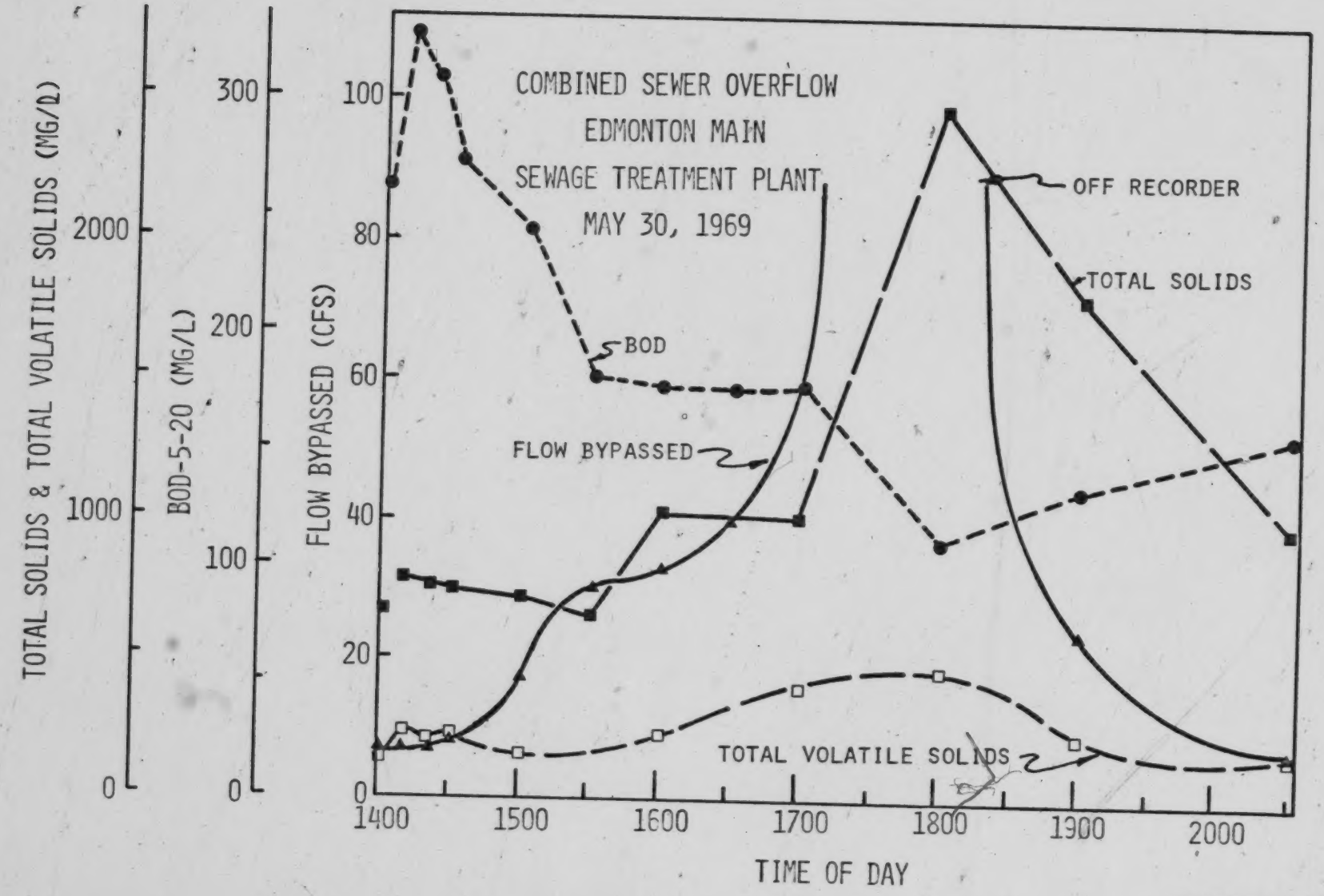

COMBINED SEWER OVERFLOW
EDMONTON MAIN
SEWAGE TREATMENT PLANT
MAY 30, 1969
TOTAL SOLIDS & TOTAL VOLATILE SOLIDS (MG/L)
BOD-5-20 (MG/L)
FLOW BYPASSED (CFS)
TIME OF DAY
BOD
FLOW BYPASSED
OFF RECORDER
TOTAL SOLIDS
TOTAL VOLATILE SOLIDS
0
1000
2000
100
200
300
20
40
60
80
100
1400
1500
1600
1700
1800
1900
2000

FIGURE D4

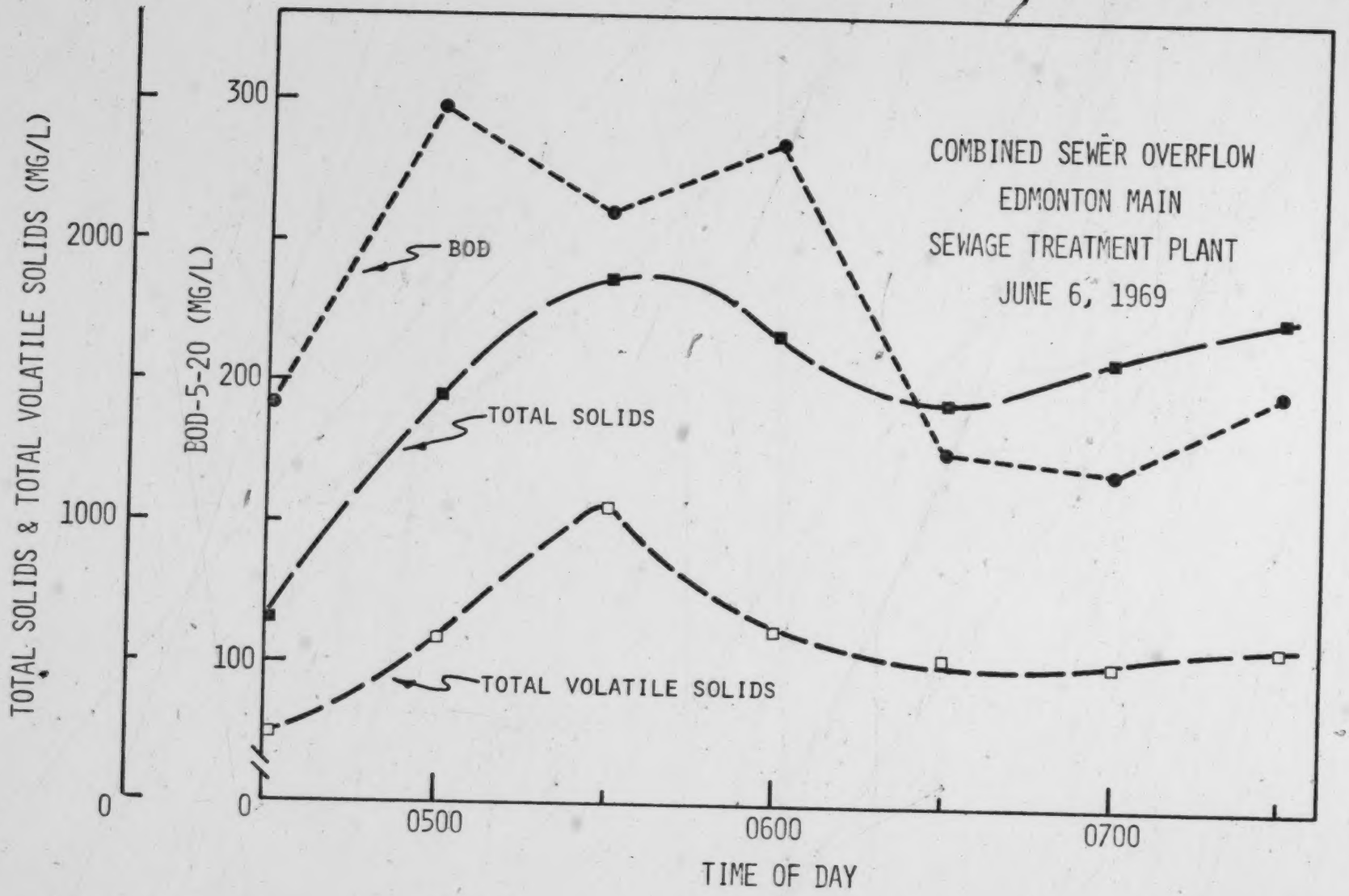

COMBINED SEWER OVERFLOW
EDMONTON MAIN
SEWAGE TREATMENT PLANT
JUNE 6, 1969
BOD
TOTAL SOLIDS
TOTAL VOLATILE SOLIDS
TOTAL SOLIDS & TOTAL VOLATILE SOLIDS (MG/L)
BOD-5-20 (MG/L)
0
1000
2000
100
200
300
0500
0600
0700
TIME OF DAY

FIGURE D5

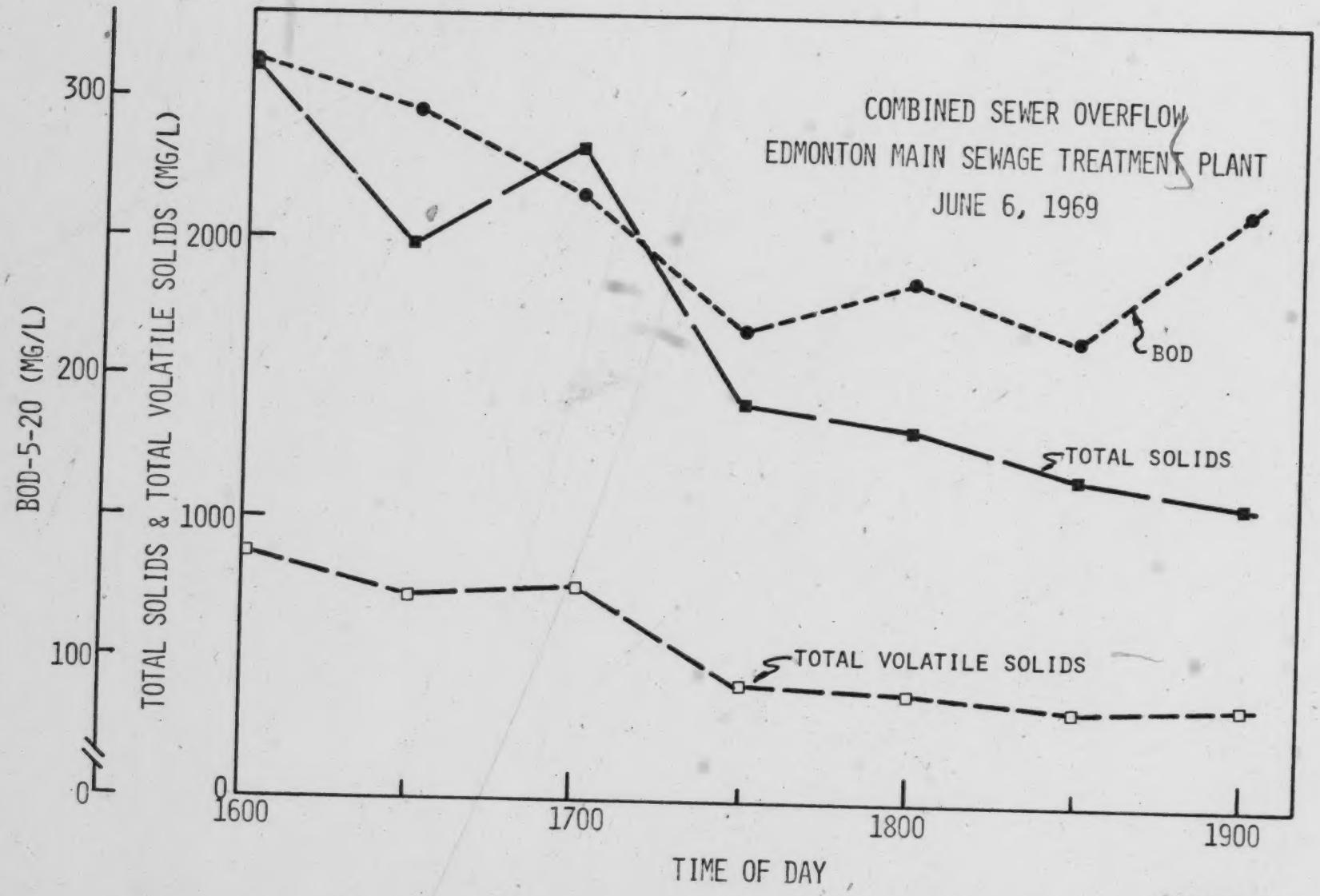

COMBINED SEWER OVERFLOW
EDMONTON MAIN SEWAGE TREATMENT PLANT
JUNE 6, 1969
BOD
TOTAL SOLIDS
TOTAL VOLATILE SOLIDS
BOD-5-20 (MG/L)
TOTAL SOLIDS & TOTAL VOLATILE SOLIDS (MG/L)
300
200
100
0
2000
1000
0
1600
1700
1800
1900
TIME OF DAY

FIGURE D6

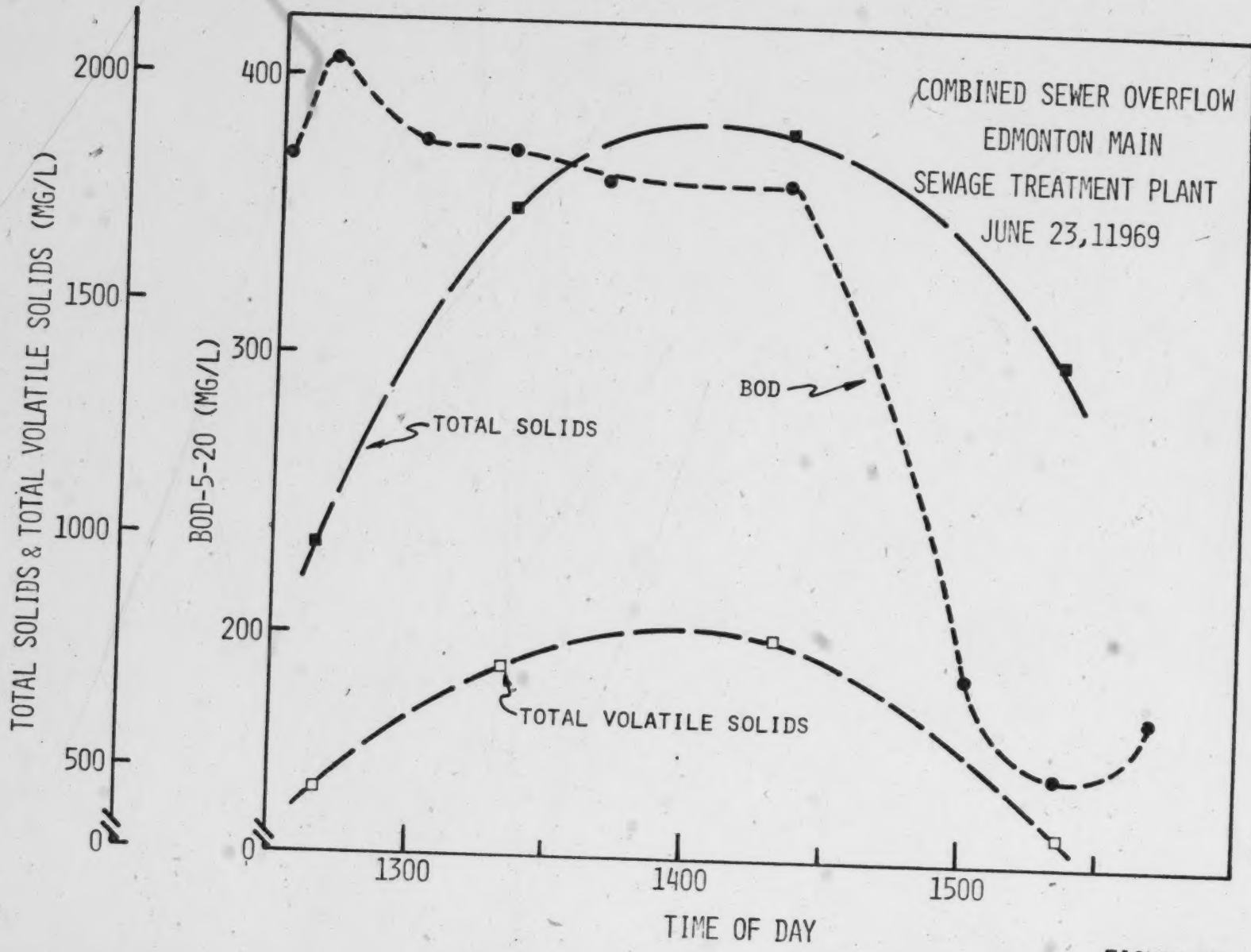

COMBINED SEWER OVERFLOW
EDMONTON MAIN
SEWAGE TREATMENT PLANT
JUNE 23,11969
TOTAL SOLIDS & TOTAL VOLATILE SOLIDS (MG/L)
2000
1500
1000
500
0
BOD-5-20 (MG/L)
400
300
200
0
TOTAL SOLIDS
BOD
TOTAL VOLATILE SOLIDS
1300
1400
1500
TIME OF DAY

FIGURE D7

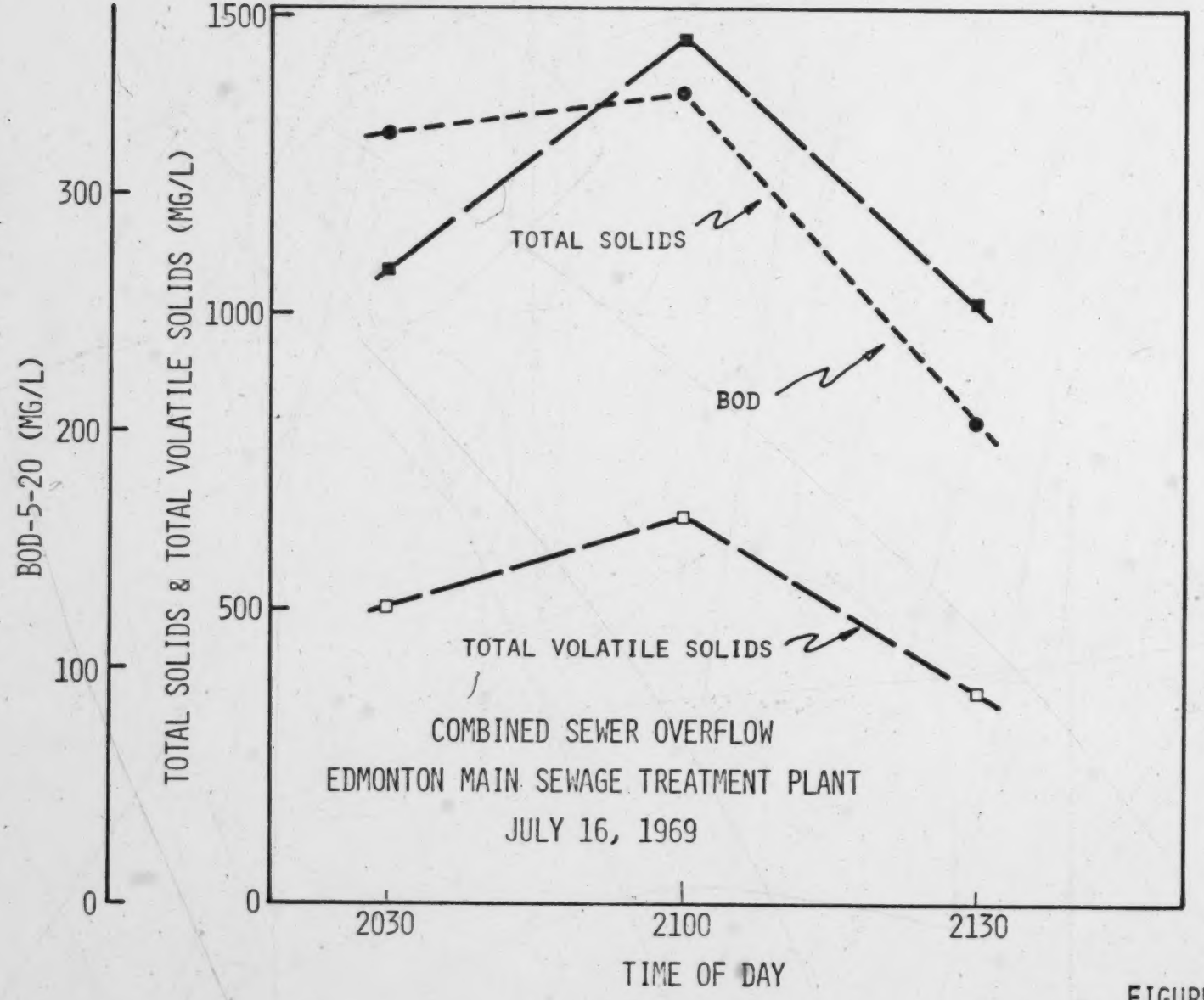

1500
1000
500
0
300
200
100
0
TOTAL SOLIDS & TOTAL VOLATILE SOLIDS (MG/L)
BOD-5-20 (MG/L)
TOTAL SOLIDS
BOD
TOTAL VOLATILE SOLIDS
COMBINED SEWER OVERFLOW
EDMONTON MAIN SEWAGE TREATMENT PLANT
JULY 16, 1969
2030
2100
2130
TIME OF DAY

FIGURE D8

APPENDIX E

RIVER WATER ANALYSES

TABLE E1

RIVER WATER ANALYSES AT FT. SASKATCHEWAN BRIDGE

June 23 & 24, 1969

Time	D.O. mg/l	BOD-5-20 mg/l	Total Solids mg/l	Total Volatile Solids mg/l	Total Fixed Solids mg/l	Conductivity umho @ 25°C	Suspended Solids mg/l	Volatile Suspended Solids mg/l	Fixed Volatile Solids mg/l
PM									
15:00	8.5	1.6	322	86	236	282	193	37	156
21:20	8.00	3.5							
21:35	7.6	3.0	362	96	266	260	192	54	138
21:45	7.5	3.0							
22:40	7.3	5.2	372	74	298	266	234	57	177
23:50	7.6	6.0	354	28	326	268	204	57	147
00:40	7.9	4.1	338	88	250	263	188	51	137
01:50	8.1	3.1	316	80	236	266	190	39	151
03:00	8.2	2.4	354	72	282	264	230	32	198

TABLE E-2

RIVER WATER ANALYSES

AT FORT SASKATCHEWAN BRIDGE

June 29, 1969

Time of Day	DO mg/l	BOD-5-20 mg/l	Total Solids mg/l	Suspended Solids mg/l	Volatile Suspended Solids mg/l
04:30	8.3	2.7	638	532	84
05:25	8.1	3.4	758	653	108
06:25	8.0	3.0	678	529	66
07:40	8.1	2.5	650	561	66

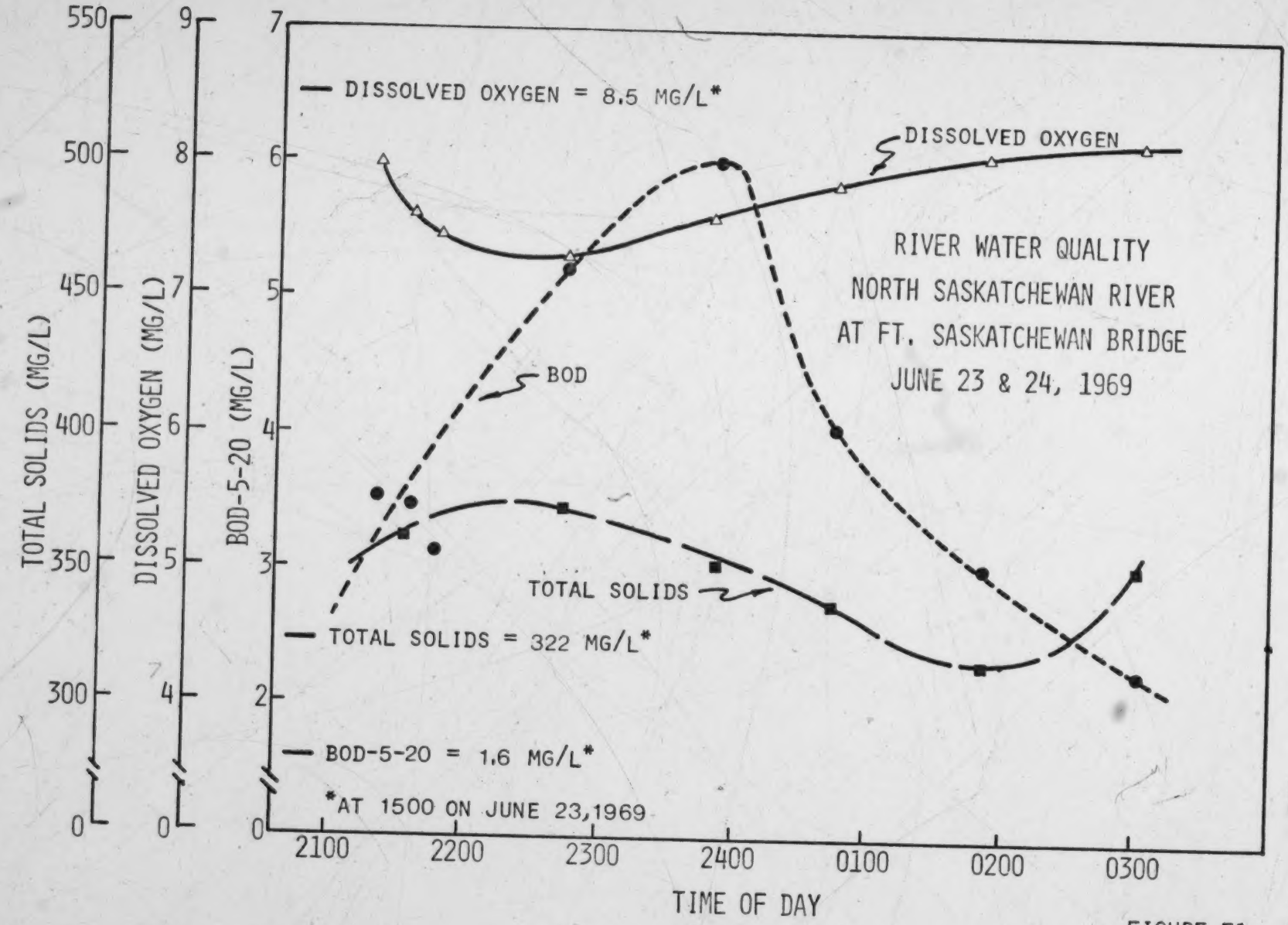

TOTAL SOLIDS (MG/L)
DISSOLVED OXYGEN (MG/L)
BOD-5-20 (MG/L)
550
500
450
400
350
300
0
9
8
7
6
5
4
0
7
6
5
4
3
2
0
DISSOLVED OXYGEN = 8.5 MG/L*
DISSOLVED OXYGEN
RIVER WATER QUALITY
NORTH SASKATCHEWAN RIVER
AT FT. SASKATCHEWAN BRIDGE
JUNE 23 & 24, 1969
BOD
TOTAL SOLIDS
TOTAL SOLIDS = 322 MG/L*
BOD-5-20 = 1.6 MG/L*
*AT 1500 ON JUNE 23,1969
2100
2200
2300
2400
0100
0200
0300
TIME OF DAY

FIGURE E1

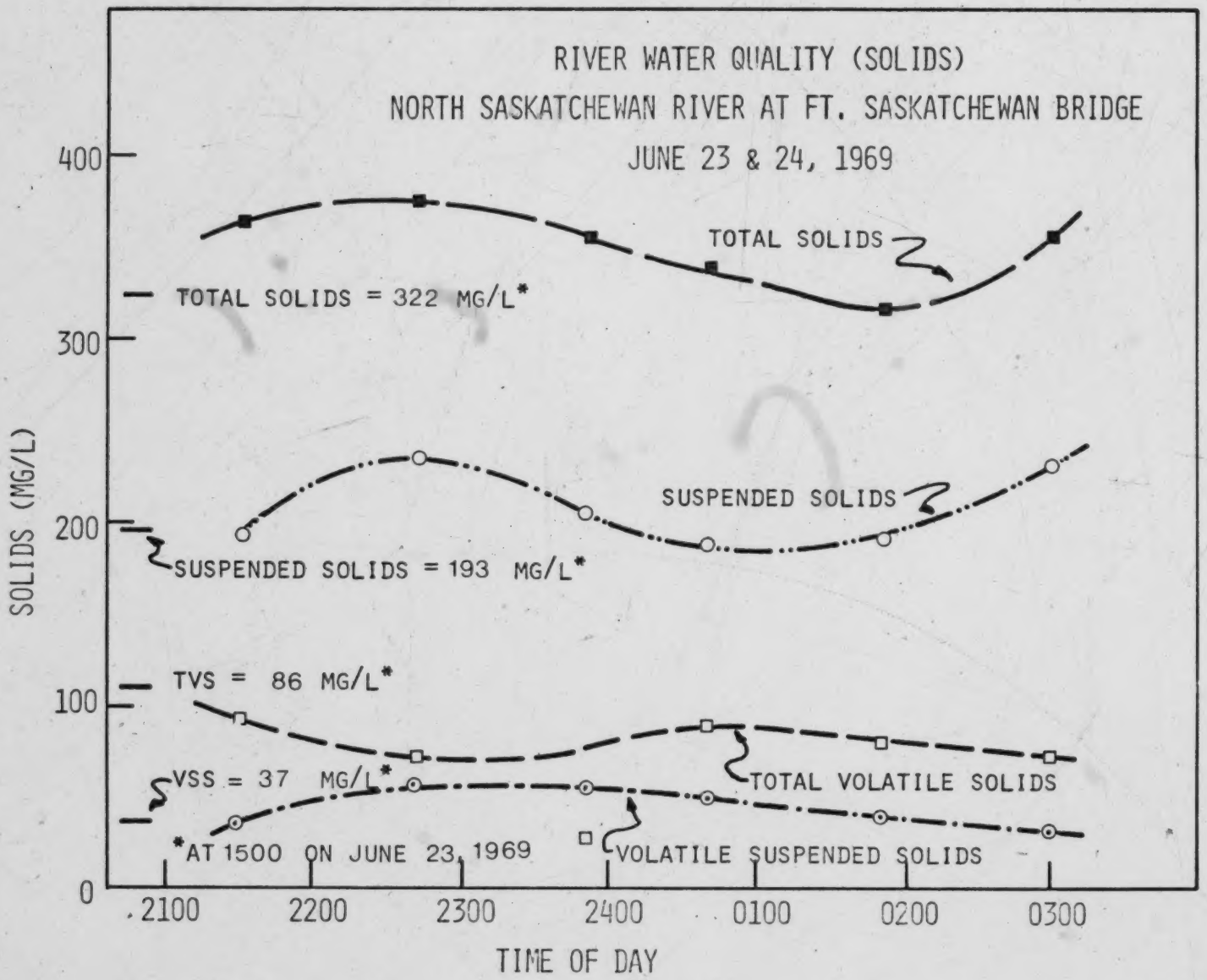

RIVER WATER QUALITY (SOLIDS)
NORTH SASKATCHEWAN RIVER AT FT. SASKATCHEWAN BRIDGE
JUNE 23 & 24, 1969
TOTAL SOLIDS
TOTAL SOLIDS = 322 MG/L*
SUSPENDED SOLIDS
SUSPENDED SOLIDS = 193 MG/L*
TVS = 86 MG/L*
VSS = 37 MG/L*
TOTAL VOLATILE SOLIDS
VOLATILE SUSPENDED SOLIDS
*AT 1500 ON JUNE 23, 1969
SOLIDS (MG/L)
400
300
200
100
0
2100
2200
2300
2400
0100
0200
0300
TIME OF DAY

FIGURE E2

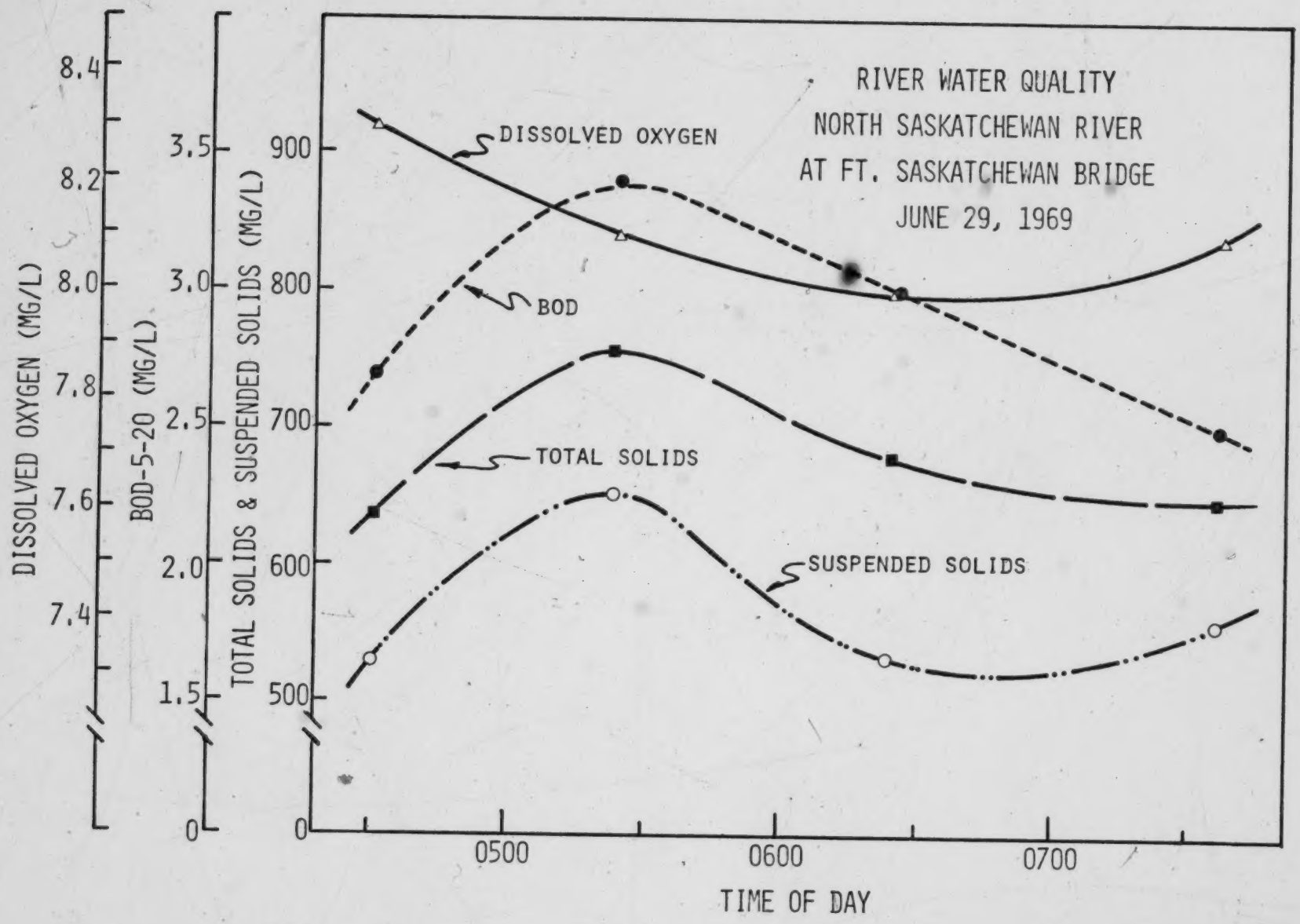

RIVER WATER QUALITY
NORTH SASKATCHEWAN RIVER
AT FT. SASKATCHEWAN BRIDGE
JUNE 29, 1969
DISSOLVED OXYGEN
BOD
TOTAL SOLIDS
SUSPENDED SOLIDS
DISSOLVED OXYGEN (MG/L)
BOD-5-20 (MG/L)
TOTAL SOLIDS & SUSPENDED SOLIDS (MG/L)
8.4
8.2
8.0
7.8
7.6
7.4
3.5
3.0
2.5
2.0
1.5
0
900
800
700
600
500
0
0500
0600
0700
TIME OF DAY

FIGURE E3

APPENDIX F

CITY OF EDMONTON SEWER SYSTEM

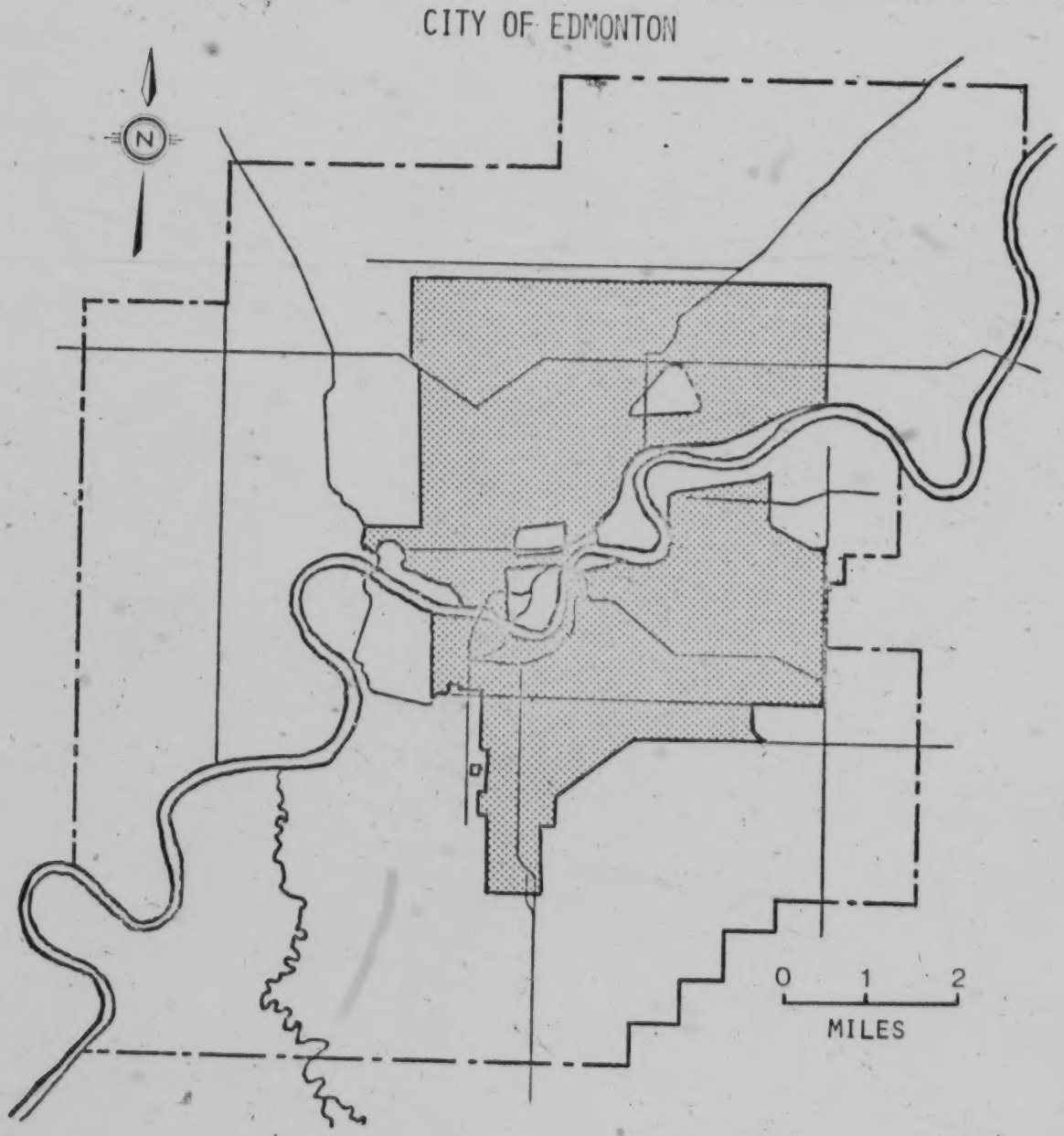
APPENDIX F

THE CITY OF EDMONTON SEWER SYSTEM

The City of Edmonton has both a combined and a separate sewer system. The combined sewer system in general, is confined to older sections of the city, although subdivisions served entirely by combined sewers have been constructed as recently as 10 to 12 years ago (ie. Ottewell). The policy of the City is that all new developments be serviced by separate systems. However, combined sewers are still being extended in the downtown area.

In 1969, combined sewers serviced approximately 40% of the serviced area and 37% of the population. (FIGURE F-1). In some areas, the combined sewers have been supplemented by relief sewers when basement flooding was experienced. Except for areas immediately adjacent to the river, the relief sewers collect and convey the street runoff to a combined trunk sewer. In areas adjacent to the river, separate outfalls have been constructed.

Most of the City's storm sewers discharge randomly to the North Saskatchewan. Also used for storm drainage courses are Whitemud Creek, Mill Creek, Edith Ravine, Kennendale Ravine and Gold Bar Ravine. There are approximately 77 storm

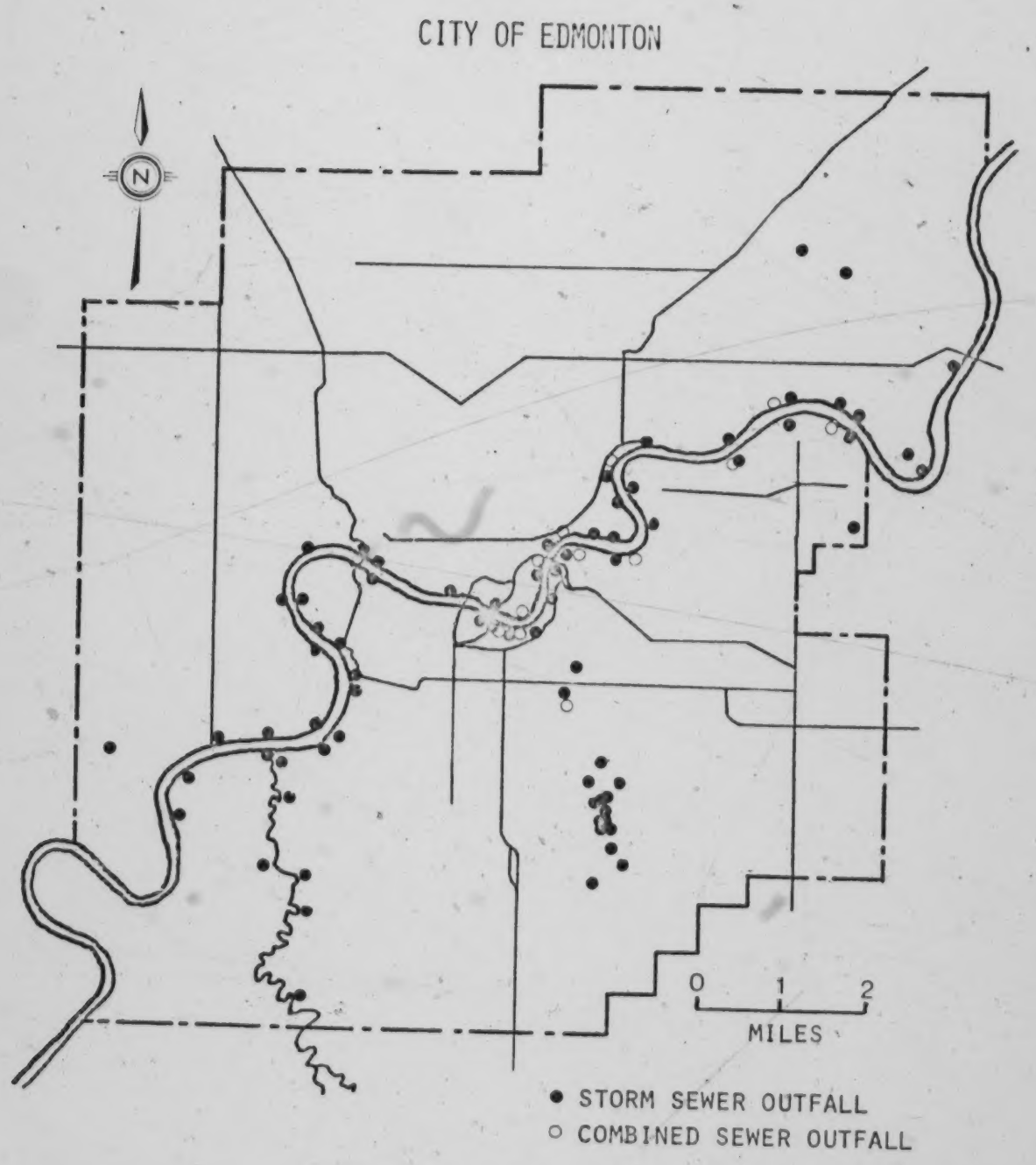


AREA SERVED BY COMBINED SEWERS

FIGURE F1

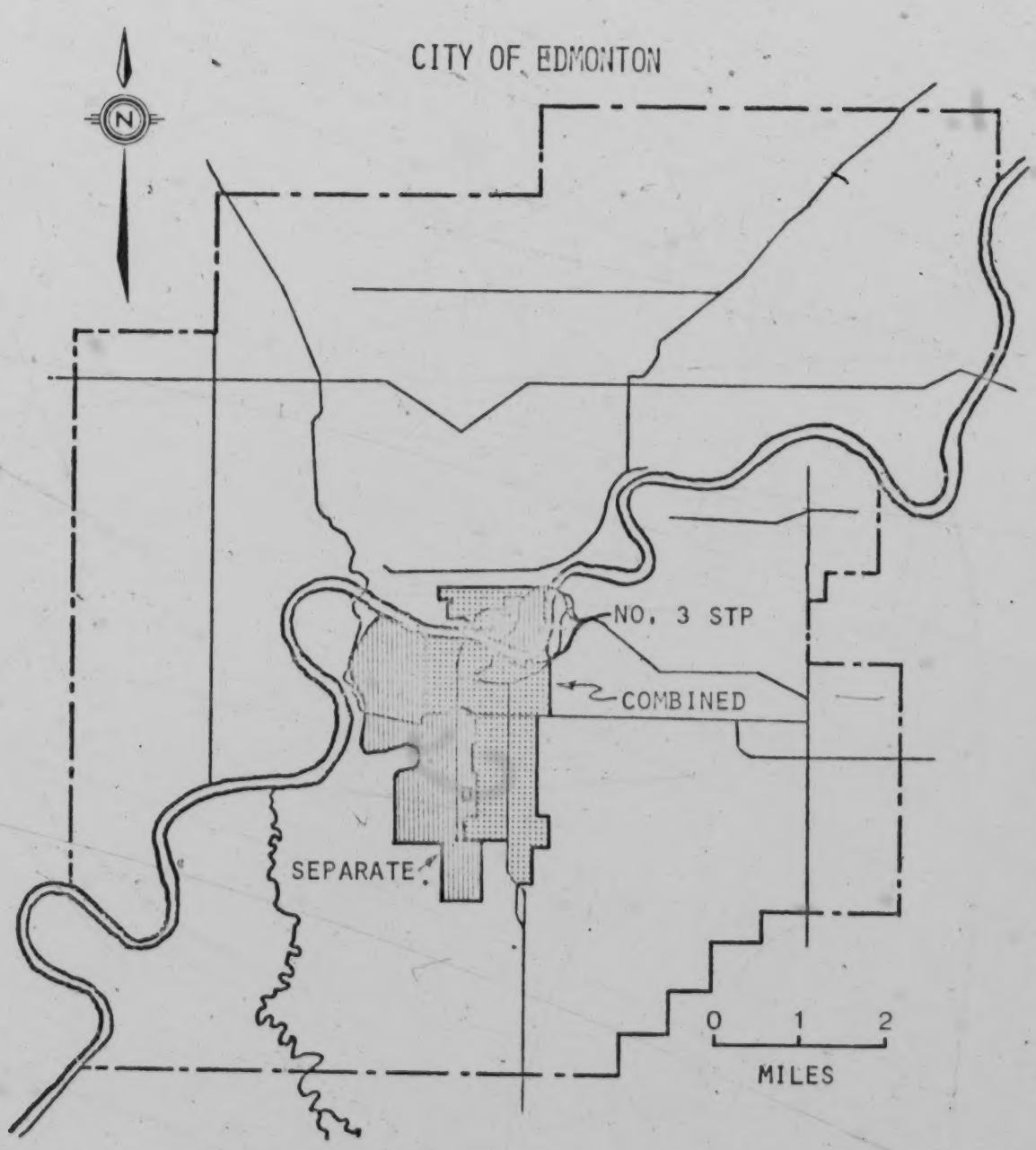
sewer outfalls in the City (January 1973). The combined sewers all overflow opposite to or downstream of the water treatment plant. There are approximately 12 overflows, one which discharges into Mill Creek, the rest directly into the North Saskatchewan River. The exact number of combined overflows could not be determined accurately since the older sections of the City have experienced much random construction of relief sewers negating detection of overflows from existing City plans. The City, if it does know the number and location of such overflows, will not devulge the information. FIGURE F-2 shows the locations of all storm outfalls and those outfalls thought to be combined overflows.

At the time of this study there were two sewage treatment plants operating in the City: the No. 3 plant located in Victoria Park and the main sewage treatment plant on 50th Street and 109 Avenue. Wastes from the packing house located in northeast Edmonton as well as some of the Beverly area are treated in a lagoon located north and east of the City. Both sewage treatment plants have combined and separate collection systems. The area contributing to the No. 3 plant is shown on FIGURE F-3. The remainder of the City is served by the main plant except the small area in northeast Edmonton mentioned above. In 1969 the summer flows through the main plant averaged 30.6 mgd while the No. 3 plant treated 3.4 mgd.



OUTFALL LOCATIONS - 1973

FIGURE F2



AREA SERVED BY NO. 3 SEWAGE TREATMENT PLANT

FIGURE F3

In 1969 the main plant had a primary capacity of 40 mgd. and a secondary capacity of 20 mgd. Flows in excess of 40 mgd. were by-passed without any treatment. The secondary portion of the plant only operated from freeze-up to break-up and could only treat two-thirds of the sewage. The remaining sewage was given primary treatment only. During dry weather the peak flows did not exceed 40 mgd. except on Mondays on which the flow peaked at 46 mgd. The main plant almost invariably by-passed during a storm.

The No. 3 plant provided only primary treatment and generally would by-pass flows in excess of 5 mgd. TABLE F-1 gives the average daily performance data for the treatment plants during the summer of 1969. The by-pass recorded at the main plant are those presented in the plant records but in fact have little meaning. The recorder on the plant by-pass could only measure up to a rate of 50 mgd. Most rainstorms were off the chart, and thus recorded at the maximum rate of the recorder.

Since 1969 the main sewage treatment plant has been enlarged. The plant now has a primary treatment capacity of 109 mgd. and a secondary capacity of 40 mgd. The plant is now required to operate all year with some by-pass permitted during summer maintenance. The No. 3 plant has been abandoned with sewage being pumped to the main plant.

TABLE F-1

AVERAGE DAILY PERFORMANCE OF EDMONTON'S SEWAGE PLANTS

Summer 1969

Main Sewage Treatment Plant

Month	Flow (mgd) Recorded By-Pass	Flow (mgd) Plant	Suspended Solids (lbs) Influent	Suspended Solids (lbs) Effluent	BOD-5-20 (lbs) Influent	BOD-5-20 (lbs) Effluent	Percent Removed S.S.	Percent Removed BOD
May	1.59	30.33	130,050	65,330	94,530	62,280	49.8%	34.1%
June	1.73	29.86	109,000	52,960	115,600	60,770	51.4%	47.4%
July	3.16	31.19	98,720	56,700	72,710	56,880	42.6%	21.8%
August	5.12	30.88	110,830	54,960	80,580	56,390	50.4%	30.0%

Number Three Sewage Treatment Plant

May	No Record	3.45	7,492	3,073	5,528	3,439	60.0%	37.8%
June	No Record	3.36	5,720	2,093	5,013	2,791	63.4%	44.3%
July	No Record	3.34	6,148	2,492	3,890	2,747	59.5%	29.4%
August	No Record	3.27	4,624	2,572	3,989	2,532	44.4%	36.5%

NOTE: Secondary Portion of Plant Taken Out of Service on May 14.

APPENDIX G

TREATMENT OF COMBINED SEWAGE

APPENDIX G

TREATMENT OF COMBINED SEWAGE

There are four basic methods of treating combined sewage. They are:

1. Storage and treatment
2. Settling
3. Flotation
4. Screening

Also, in some areas, usually where the receiving waters are used for recreation, the combined sewer by-passes are chlorinated.

The most effective method of treating combined sewer overflow is to store it during the runoff period and then pump it to a conventional sewage treatment plant for treatment. If the amount of combined sewage involved is not too great a treatment plant sized for dry weather flows can handle the additional loading during off-peak hours. If adequate land is available and aesthetics is not considered a problem, the most economical method of storage is in lagoons located at the outfall. Aeration can be added to the lagoons to keep the sewage "fresh", thus cutting down odor problems and help keep the material in suspension. Unfortunately, in most cities,

the combined sewers are located in built up areas and adequate land is not available. In Boston and Chicago this problem was solved by constructing large underground tunnels in rock to temporarily store the combined sewer overflow. In other areas, cities have given consideration to the construction of large inflatable tanks submerged in harbours or lakes which would inflate when filled with combined sewage overflow and then deflate when the sewage is pumped out.

Combined sewer overflow can be given primary treatment by settling in a conventional clarifier or passing it through a short retention lagoon. The degree of treatment is expected to be similar to that obtained in a primary sewage treatment plant (30 - 40% removal of BOD-5-20 and 35 - 50% removal of suspended solids). A study in Chipawan Falls[25] indicated that overall removal of BOD-5-20 and solids is inconsistent and on the average not as good as expected.

Recent work on swirl concentrators[18] indicated that if properly designed, they can be very effective in the removal of the settleable solids in the medium and larger grain sizes, the removal of smaller grain sizes is less efficient although still appreciable. A swirl concentrator is a circular channel in which the incoming sewage is dispersed and follows a spiral path. The solids tend to concentrate in the lower portion of the chamber and are discharged to a treatment facility through a foul sewer outlet. Excess flows

pass over a central circular weir and are disposed of. There is no indication of how effective the swirl concentration is in removing BOD-5-20.

The screening and flotation process was tested on combined sewer overflow in Milwaukee, Wisconsin (20). Utilizing chemical flocculents (ferric chloride and a cationic polyelectrolyte), removal of 65 - 80% of suspended solids and volatile solids were consistently obtained. BOD-5-20 and COD removals were slightly less at 55 to 65 percent. Without chemical aids, the removal of BOD-5-20, COD, suspended solids and volatile solids dropped to the range of 40 to 50 percent removal.

Using screening alone, a 50 mesh screen at 40 usgpm/sq. ft. had average removal efficiencies of 26 percent for BOD-5-20 and COD. The percentage removal of suspended solids and volatile solids was 27 and 34 percent respectively.

The material removed from the process has to be pumped to a sewage treatment facility for final disposal.

It was estimated that a large screening - flotation facility would cost $21,000 per million gallon per day (U.S.) and have an operating cost of $3,090 per mgus of treated overflow.

APPENDIX H

METHODS OF DETERMINING URBAN RUNOFF

APPENDIX H

METHODS OF DETERMINING URBAN RUNOFF

There are two objectives in examining the hydraulics of an urban area. The first is to determing the peak runoffs of an area for the proper sizing of the drainage system. The second is to determine the volume of runoff such that the pollution loading to the receiving stream can be determined, and also to facilitate the design of retention ponds to act as surge relief, or where the system is combined, to determine the sizing of treated facilities. The following is a summary of the various methods commonly used in assessing urban systems.

RATIONAL METHOD

The method was first introduced in 1889 and is still used by more than 90 percent of the engineering offices in the United States. The formula is:

$$Q = CiA$$

where C is a coefficient, A is the drainage area and i is the average rainfall intensity for the period of maximum rainfall at a given frequency of occurrence. The rational formula makes the following basic assumptions:

1. The rate of runoff to any point under consideration is a function of the average rainfall rate

during the time required for the water to flow to that point from the furthest point in the drainage area (time of concentration).

2. The peak rate of rainfall occurs within the time of concentration.

The area to be used in the calculation can be determined by simply measuring from a scale drawing or an air photo. The drainage area should be subdivided into component parts contributing to inlet points. When investigating any drainage area, the land use, the percentage of imperviousness, the characteristics of the soil and the magnitude of the ground slopes should also be known.

To determine i, the intensity duration, the frequency relationship has to be developed from existing rainfall data for that region. There are several methods of deriving this relationship which are discussed in the references. In general, the relationship for a given frequency and duration of less than two hours can be expressed mathematically by an equation of the form

$$i = \frac{A}{t + b} \quad \text{or} \quad i = \frac{A}{t + b^n} \quad \text{or} \quad i = \frac{A}{t^n + b}$$

in which i is the intensity in inches per hour; t is the duration in minutes; A and b are abstract constants and n is an exponent.

The frequencies most commonly used for the design of storm sewers are two to ten years for residential areas, (most cities use 5 years), and ten to fifty years for commerical and high value districts depending on the economic justification.

The runoff coefficient is the most indeterminant variable of the rational formula and calls upon the judgement of the person using it. The amount of runoff from a storm is reduced by evaporation, depression storage, surface wetting and percolation. These losses reduce as the storm progresses giving rise to a C value which varies with the duration of rainfall. Hoad expressed this relationship as

$$C = \frac{a^t}{t + b}$$

in which t is the duration in minutes and a and b are constants dependent on the characteristics of the drainage basin. This relationship is almost never used in actual design practices but rather a constant value of C is selected. In the city of Edmonton, the most commonly used values of C are 0.4 for residential areas, 0.6 for industrial areas, and 0.8 for downtown commercial areas.

In utilizing the rational method, especially for the design of storm sewers, the time of concentration should be

determined. It is composed of two parts; the time required for storm water from the furthest part of a drainage basin to obtain entrance to a sewer and the time of flow in the sewer. The surface travel time or inlet time is a function of the surface roughness, the depression storage, the steepness of slope and the size of the area drained.

A relationship was derived by Kerdy(26)

$$t = \left(\frac{2}{3} \; L \; n / \sqrt{s}\right)^{0.467}$$

in which t is the time in minutes, L (< 1200 ft.) is the distance of the farthest tributary point, s is the slope and n is the retardance coefficient analogous to the coefficient of roughness. In practice, an inlet time is generally assumed rather than calculated.

The rational formula is most widely used in obtaining a peak value of runoff for the design of a storm sewer system. First, the drainage basin is divided into subbasins each of which contribute to an inlet. The inlet time for the subbasins is calculated or assumed and the intensity for that duration is obtained from the intensity-duration-frequency curve. The intensity is then multiplied by the area of the subbasin and the assumed runoff co-efficient. The resulting value is assumed to be the intensity of flow at the inlet. The time for the flow to travel through the underground pipe is then calculated, and added to the initial inlet time,

giving a new time of concentration. The new area of the next basin is added to the previous basin, the intensity determined from the new time and runoff from the combined basins determined. The flow is then carried on to the next basin and the process repeated for all the sub-basins.

The rational method is also used to calculate the total runoff from a basin by assigning the basin a particular storm and multiplying the total rainfall by the assumed runoff co-efficient and the area.

The rational method usually produces satisfactory results when understood and used properly. Its main criticism is that it does not represent actual events that occur during a storm.

Chicago Hydrograph Analysis (27)

This method was developed by the City of Chicago to isolate and evaluate all the influences which would translate the time intensity pattern (hyetograph) of rainfall into a sewer flow hydrograph for a unit drainage area.

This method considers the influence of:

(a) Infiltration capacity of previous areas

(b) Depression storage

(c) Overland flow detention

(d) Detention in gutters, catch basins, house drains and lateral sewers.

Briefly the steps followed in the Chicago method of analysis are as follows:

STEP 1. Determine a rainfall duration-intensity curve for the frequency of design.

STEP 2. Determine the storm pattern or hyetograph for those storms which are most likely to cause excess runoff.

STEP 3. Determine the relationship between the rainfall hyetograph and the hydrograph of flow entering surface channels for pervious areas considering infiltration and depression storage, surface retention, and length of overland flow.

STEP 4. Determination of the hydrograph from inpervious areas.

STEP 5. Routing of the flow from the pervious and inpervious areas into and along channels or street gutters to inlets using a storage equation.

STEP 6. Determination of hydrograph from building roofs.

STEP 7. Route the hydrographs of street inlets and roofs into lateral storm sewers.

STEP 8. Route the lateral flow hydrograph by the time-offset method to the point of discharge.

To facilitate using this method various curves can be set up to give the designer the depression storage for various

types of land use, the effect of changing the surface slope of pervious and inpervious areas, the effect of various percentages of directly connecting inpervious surface and various travel times in laterals.

This method has proven successful in Chicago. This is due to an extensive knowledge the designers have about local conditions and uniform development in small rectangular sections. It would be difficult to apply this method to small urban areas where it is not practical for designers to gather the background information.

The B. R. L. (British Road Research Laboratory) Method (19)

This method devised in early 1960 is now used for 80% of the design or redesign of storm drainage systems in Great Britain. The use of this method requires that the designer have a computer available.

This method only deals with the runoff from directly connected paved areas. Areas that are grassed or are not directly connected to the drainage path are excluded from the calculations.

Each urban drainage basin is divided in sub-basins and the rainfall for the storm under investigation is divided into uniform increments of time. The increments of rain are then applied to the paved area of the sub-basin and the travel time of each increment to reach the inlets on the downstream

end of the sub-basin calculated. A surface hydrograph for each sub-basin is then calculated. These hydrographs are then routed through the underground piping and allowance made for temporary storage within each section of pipe. The combination of hydrographs for each section of pipe produces the hydrograph of the outfall.

This method was tested recently in ten urban basins in the United States (19). It produced results suitable for the design of a storm drainage system in three of the ten cases. It was found to break down when runoff from grassed areas of basin became significant. This occurred when the slope of the basin was steep, when the paved area was less than 15% of the drainage basin or when storms of a high frequency occurred.